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PREFACE

IT was interesting to talk to Kings of Commerce and to learn how they rose to fame and fortune; before writing *Heroes of Modern Adventure* and *More Heroes of Modern Adventure* we were privileged to hear intrepid explorers relate their stories of endurance and heroism in quest of the unknown that have thrilled the world. But when gathering material for the present volume we found even greater romance—the romance of knowledge that little by little is solving the secrets of nature and revolutionizing the world in which we live.

Not much more than a century ago people laughed at Galvani for making a frog's leg twitch by the application of an electric current, and less than a hundred years have passed since Faraday was tinkering with magnets and wire. Those people who asked " What's the use? " did not dream that these men, with Volta, Humphry Davy, and a few others, were initiating the mighty changes in the conditions in which we live brought about by the development of electric light, electric power, the telephone, and wireless.

Barely fifty years ago even the schoolmaster thought little of Science. The average schoolboy got an hour weekly of what he called " stinks " and regarded it as a splendid opportunity for taking it easy and sucking sweets. Science was looked upon as something apart from ordinary life, and many, especially religious people, hated and feared it. George Gissing wrote: " I see it restoring barbarism under the mask of civilization. I see it darkening men's minds and hardening their hearts."

If Gissing had lived to see the Great War he might have felt that his fears were realized, especially when poison gas swept in waves over the trenches and high explosive bombs killed women and children in the streets of great cities. Yet that same gas, chlorine, has its proper use in bleaching cloth, and the explosives their real value in blasting tunnels through mountains, or breaking up coal in a pit. It is not fair to blame a useful article because it is put to a bad use.

Science, properly used, has saved far more lives than science badly used has destroyed. Medical Science has reduced the annual death-rate in Great Britain from seventy per thousand to less than fourteen within little more than a century; it is wiping out infectious diseases—in the end it will utterly destroy them. Chloroform is a poison which will kill, but think of the amount of agony which our ancestors suffered before this anæsthetic was discovered! In Nelson's day when a wounded man had to have a leg or arm amputated those near by would stuff their ears with cotton-wool so as not to hear his screams.

Look back farther still at what we call the Dark Ages. For centuries man had stood still; the ordinary citizen enjoyed little comfort in his life; prejudice and persecution reigned supreme. In the middle of the fifteenth century printing was invented; printed books made known to many knowledge that had long been lost for all practical purposes; yet it was not until the seventeenth century, when that great genius Sir Isaac Newton began his work, that real Science was born and the world awoke from its sleep.

For a long time progress was slow. Even at the beginning of the nineteenth century there were no railways; it took a week to travel from London to Edinburgh, and more than a month to cross the Atlantic. Nearly everything that man required was still made by hand. A pair of the commonest boots cost two pounds, and a suit of rough clothes five or six pounds. Windmills and water-mills were used, but steam was only just beginning to be thought of as a motive power. There was no gas or electricity, and when coal gas was first used in the House of Commons members were seen touching the pipes to see if they were hot. They actually believed that the gas came through the pipes as flame. Telephones, telegraphs, electric tramways, photography, motor-cars, aircraft, none of these had yet been dreamed of.

Slowly at first, but with ever-increasing speed, Science began to alter conditions, and during the nineteenth century it completely changed the face of the civilized world. Trade, transport, and education were revolutionized; food, clothes, all the necessities of life, were made cheaper and more plentiful; the poorer folk were given comforts and conveniences of which even the rich had known nothing a hundred years before. Science shed light upon dark places, and it has linked up the whole world.

During this present century the power of Science is increasing like a snowball. There is more progress now in one year than there was in ten during the nineteenth century, and the pace is becoming constantly faster. Chemists are working in all fields of endeavour, and hardly a week passes without some important discovery being announced. Read the chapters in this book on the Curies and the work of Sir William Bragg and you will realize that the discovery of radium is perhaps the most important event in the history of man. It has changed our whole conception of the universe.

Old-fashioned folk talk much of the restlessness and discontent of the present generation. But these are only natural in a time when things are moving so fast—in what we call an age of transition—and they are not really bad in themselves. After all, we do not want people to act like sheep. Discontent may be divine.

For better or worse—and we think it is for better—scientists are the rulers of the world. Look back and you will see that the work of Stephenson had a far greater effect on man's destiny than the conquests and law-making of Napoleon.

Yet scientists are very modest folk. We did not find it easy to persuade our subjects to talk of themselves, and our chapters are not in any sense stories of their intimate lives. There is, however, no less interest attaching to the wonderful work they are doing, or have already done, of which we have told.

It has not, of course, been possible to do more than touch the fringe of the subject. We might easily have selected two hundred names instead of twenty. Our idea has been not merely to choose the greatest scientists of the present day, but rather to present as many different aspects of Science as possible, and to procure the material in each case from the one best able to give it. With two exceptions, all our subjects are alive at the time of writing. The exceptions are Luther Burbank, the Californian plant wizard, and Professor Curie.

Our chief difficulty has been to put the mass of material given to us into simple and readable language. Science in these days has a language of its own, and if we have erred here and there in trying to simplify technical terms we must beg the reader's indulgence.

Our task has entailed much travelling and interviewing—work which has been lightened by the very great kindness of those interviewed. Your modern scientist is one of the world's hardest workers, and it is real charity on his part to give up two or three valuable hours to a stranger who comes asking him endless questions.

Among those who have given us special assistance, and to whom, therefore, special thanks are due, are Sir William Bragg, Sir Ernest Rutherford, Sir Oliver Lodge, Mr J. B. S. Haldane, Sir Robert Robertson, Director of the Government Laboratory, Sir Ronald Ross, Sir Frank Dyson, Sir John Snell, Sir Charles Parsons, Sir Daniel Hall, and Sir Joseph Petavel, Director of the National Physical Laboratory.

The facilities given us include permission to quote from published works in compiling some of our chapters, and for this additional help we make grateful acknowledgment.

It may be said that this volume is published with the authority and consent of many of the distinguished scientists whose achievements it relates. We hope their kindly assistance will be justified by the interest the book will awaken in those who are eager to know more of the notable conquests of Science in our own day.

T. C. Bridges
H. Hessell Tiltman

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CHAPTER I

THE WONDER OF WIRELESS SIGHT

John L. Baird, Pioneer of Television

WHEN the telephone was invented by Graham Bell more than fifty years ago, and the world was thrilled by the possibility of hearing voices over great distances, some one remarked that " We shall be seeing at a distance next."

Many thought that the prophecy was a joke, but the brains of scientists have a habit of ' worrying ' at problems tirelessly, and even one as difficult as this is at length solved. Though baffled again and again, keen minds maintained the endeavour to fulfil that prophecy, until one day in October 1925 a young Scottish inventor, poor and unknown, was working alone in a London attic when suddenly he saw on the screen of his home-made apparatus the image of a dummy head that was in the next room. The prophecy had become a scientific fact—that inventor, the first man in the world to see through a brick wall, as it were, had made television possible, and ensured for himself an enduring place in the history of scientific research.

But that is anticipating our story. To appreciate that achievement in a Soho attic one must know something of the long search for the secret of television and of John Logie Baird, the remarkable and patient scientist who has given humanity ' long-distance eyes '—the ability to see persons and objects thousands of miles away.

Television, or its equivalent, had been a dream of centuries. Most people regarded it as just a dream, like the search for the food of the gods, or the elixir of life, and no more capable of fulfilment than are many other miracles which man would like to perform, but cannot.

But an increasing number of dreams equally 'far-fetched' had materialized during recent decades. Already it was possible to turn night into day by pressing a switch, to talk over vast distances, to operate without pain, to show upon a screen crude, flickering reproductions of animated scenes. But actually to see through walls—it simply could not be done. Nevertheless there were scientists who were wrestling with the idea of wireless, of speaking and seeing over long distances without an intervening wire, and within a few years of the first conversation on the telephone there was to be born near Glasgow the Scottish boy who was destined, before attaining the age of forty, to solve this problem of television. John Logie Baird, after whom the Baird Television Development Company, Ltd., is named, would be the first to agree that his twin inventions of television and noctovision (seeing in the dark) have not yet reached perfection, but enough has already been done for the story of his achievements to be one of the romances of the age.

To retell, even briefly, the history of the scientific facts behind television would need the whole of this book. We should have to go back to 1873, when the light-sensitive properties of selenium were discovered, and the first fractional part of the riddle—the possibility of turning light into electrical impulses—was solved.

But selenium proved too slow in action to assist those who sought to make television possible. The author of *Television for the Home* says:

> It should be realized that television is not really a question of transmitting and receiving a number of images each second, for an image cannot be sent or received as a whole. Each image has to be broken up into thousands of tiny fragments and reassembled by the receiver in a fraction of a second. The practical problem in television was how to transmit nearly

100,000 signals per second, and it was at once realized that this problem was on quite a different plane to the ordinary wireless problem, such as sending signals by dots and dashes.

By the aid of selenium pictures were reproduced by telegraphy in 1907, when a picture of King Edward VII was transmitted in twenty minutes by a German named Korn. Since that date the sending of pictures by telegraphy has made rapid strides, and illustrations transmitted over great distances in this way appear regularly in our newspapers. But these later developments, even had the results been available, would not have helped those who in the closing years of the last century sought the key to television, because with a picture it was not necessary to transmit and receive the whole production in a fraction of a second, whereas if television was to be successful some method of sending nearly 100,000 signals per second must be discovered.

More valuable was Hertz's discovery, in 1888, of wireless waves which made broadcasting possible. Another step had been taken toward seeing at a distance, but still both the possibilities of the invention and the method were undiscovered.

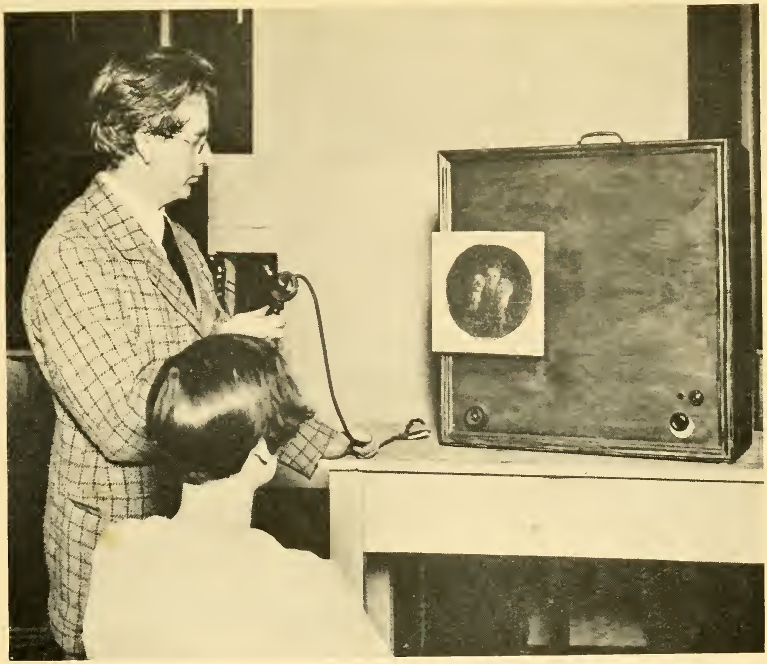
The Hertzian waves and the discovery of photo-electric cells made it possible to transmit scenes infinitely faster than had been possible by selenium, but here another difficulty arose. The photo-electric cells were not sufficiently sensitive, and would not respond to the small light available. Shadows only were received—there was no known method of amplifying the impulses sent out. Thus it was found that if a human face were brilliantly illumined by powerful lamps, the reflected light caught and transmitted was less than one candle-power.

For some years there was no further advance, until developments in wireless, especially Sir John Fleming's invention of the thermionic valve, encouraged the pioneers of television to redouble their efforts, for the new valve provided a means of amplifying the most minute currents of electricity to almost any extent. But once more disappointment was ahead. It was found that for successful television an amplification at least a thousand times greater than that obtained by Sir John Fleming's valve would be required.

It will be seen, therefore, that the real stumbling-block to the successful production of wireless sight for fifty years was the discovery of a light-sensitive device speedy enough, and sensitive enough, to permit the transmission not of vague shadows, but of clear, sharp, complete pictures, at the speed of twelve or more per second.

In other countries—in the United States, France, and Germany—patient investigators were at work on these problems, but between the discovery of the light-sensitive properties of selenium in 1873 and Baird's first successful experiment in the transmission of shadows in 1925 there stretch fifty years of heart-breaking disappointments—fifty years during which apparently no progress was made. This period, however, was really that of a strenuous international race for the honour of achieving television, and the prize was won by a Scottish engineer who fought ill-health, discouragement, and lack of funds, to experience at last the thrill of watching, not a vague shadow, but a face having expression, with light and shade, all this being conjured by the inventive genius from the apparatus to the creation of which he had so tirelessly devoted himself.

John Logie Baird is the son of a Scottish Presbyterian minister, and was born at Helensburgh. While still a schoolboy he showed signs of the inventive instinct which was later to dominate his life. It was then that he set up a model telephone exchange by his bedside to connect him with four friends living near by. The telephones were precariously connected by wires hanging across the village street, and it was this fact that brought John Baird's first effort at construction to an untimely end, for



JOHN L. BAIRD GIVING AN EARLY DEMONSTRATION OF TELEVISION

The image of a person holding two dolls is seen on the little screen. 'Seeing by wireless' has made big strides since this photograph was taken.

one rough night a wire was blown down, and, catching a passing cabman round the neck, it jerked him off his cab. Thinking that the wire had been erected by the newly formed National Telephone Company, the cabman promptly complained to them, and thus it was discovered that they had an unauthorized rival in the field.

There followed other experiments with an antiquated motor-car which Baird purchased and pushed home to the manse where he lived, while later he cultivated his intense interest in the new world of science then being opened up by studying at the Royal Technical College and Glasgow University, and thereafter by serving as an apprentice in a motor-works.

In this first situation he developed that capacity for hard work which was afterward to be so invaluable in his prolonged one-man experiments. The works opened at 5.30 A.M., and overtime was the rule rather than the exception, so that during most of the year Baird left home before daylight and did not return until late at night.

He left the motor-works to take up a post under the Scottish Electricity Commission as Assistant Superintendent of the Clyde Valley Electrical Power Company. War came, and he volunteered for service, but was rejected as physically unfit. He returned to his post in the Power Company, and throughout the War he worked on the machines which supplied power and light to the munition factories and shipyards of the Clyde. Ill-health at last caused him to resign, and it was then that he resolved to use part of his enforced leisure to seek the clue which would make television possible.

His research work was interrupted by the necessity of rebuilding his health. Immediately after the War he had invented a patent sock which kept the feet warm and dry in any weather. The sock sold widely, and money was beginning to flow in when it became necessary for him to abandon business cares for a time, so that he sold out his business to a Glasgow merchant.

A visit to the West Indies followed, and upon his return he had to look round for further work which would provide him with a livelihood.

For a time he bought and sold Australian honey, and with the profits made on this side-line he bought an interest in another firm, which sold coconut dust as a fertilizer. The business proved very profitable, but once more his health broke down, and he was ordered a complete rest. He went to Buxton, and in August 1921 came back to ' start all over again.'

He built up another business, this time selling soap, but once more his health proved unequal to the strain of commercial life. He suffered a nervous breakdown, this being so severe that the doctors told him that he must abandon for ever the thought of a business career.

There must have been very little hope in the heart of the young Scot when he left London for the third time to live quietly in Hastings, on the South Coast. Yet had he but known it, he was at that moment within two years of the beginning of discoveries for which his name will always be honoured.

Debarred from active business life, he turned once again to scientific research, and it was natural that the particular branch of science which attracted him should be the investigation of television, to which he had been so strongly attracted when a student.

During the years when he had been working as an engineer and as a business man others had been struggling with this very problem. But they had made no progress; the search for the secret of television remained where it was when Baird had been a student at Glasgow.

He settled down to work in a room over a shop in Queen's Arcade, Hastings, and it was here that his first small step toward television was successfully accomplished six months later. Before an audience which included William Le Queux, the novelist, Baird transmitted coarse shadows from a transmitter to a receiving apparatus. A tiny step forward, and others, including Jenkins, the American inventor, had accomplished as much, but it fired Baird's hopes.

The authors believe that that first successful experiment at Hastings will be associated in history with the first electric light and the first flight of the Wright brothers. It was achieved with an apparatus made out of an old tea chest and an empty biscuit box. The projection lens was a bull's-eye lens costing tenpence; the driving mechanism was a toy electric motor which cost less than six shillings.

Through this home-made apparatus Baird's visitors saw on the screen of the receiver a small flickering Maltese cross. It was a small achievement, but a report in the Press aroused the interest of a cinematograph proprietor, who sought out the young inventor and bought a third share in the work for £200.

Twelve months later Baird had succeeded in transmitting outlines of simple objects in black and white. The step from shadows to reflected light had been taken, and Baird was ready to return to London, there to seek the interest and the funds without which he could not continue his work much longer.

Hastings has since commemorated Baird's association with the town by means of a tablet placed on the walls of the shop where he achieved his first success.

In London Baird secured as his workroom an attic in Frith Street, Soho, close by the room in which Freize-Green had invented the first crude cinematograph machine, about the time when Edison was experimenting with his kinetoscope. Baird felt convinced that television was now just round the corner, but, like many another inventor, he was to face a dark hour before seeing the dawn of his hopes.

Money ran short. He found it difficult to secure even food. For days he wandered round London with threadbare clothes, seeking the funds which would enable him to continue his work. No one was interested in television because none believed it to be possible. Despairing, he turned at last to friends, who responded generously. Money was forthcoming, the first tiny company was formed, and the great search for wireless sight was renewed with fresh vigour.

One wonders how Baird feels about that dark chapter when he stands beside the case in the Science Museum at South Kensington wherein is preserved for the nation the crude television apparatus with which he transmitted those first outlines, and remembers that for the sake of improving it he went without bread.

The real turning-point came soon after funds were placed at his disposal. In March 1925 Mr Gordon Selfridge, hearing of the remarkable experiments which were taking place in that attic room in Soho, and quick to realize their importance, visited the laboratory. There he was given a demonstration and saw transmitted from one room to another a crude outline of a paper mask. This mask was made to wink by covering one of the eyeholes with white paper, and its mouth could be opened and closed by the covering and uncovering of the slot in the white paper which represented it.

It was a very elementary experiment, but it convinced the Store King that television was at last coming, and he arranged to pay a substantial sum to have it demonstrated at his store for two weeks. Thus it was that the first public exposition of the wireless transmission of visible outlines was given in Britain by Baird.

This public demonstration aroused great interest. The layman who expected to see a perfected brass apparatus and mechanism may have been unimpressed by Baird's weird conglomeration of makeshifts fastened together with string, glue, and sealing-wax, but in the scientific world the importance of his advance was recognized.

The demonstration given in April 1925 showed only the transmission of outlines, and nothing in the shape of a human face or any object having light and shade or detail could be reproduced. At the end of the fortnight, therefore, the apparatus was hurried back to Soho, where more months of tireless experiment passed before the remaining problems were at length solved. The most dramatic moment in the history of television cannot be better described than in the inventor's own words:

> It was on an October afternoon in 1925 that I experienced the one great thrill which research work has brought me. After weeks of steady progress, on this particular afternoon the dummy's head which I used for experimental purposes showed upon the receiving screen not as a black and white effect, but as a real image, with details, and with gradation of shading. I was vastly excited and ran downstairs to obtain a living object. The first person to appear was the office boy from the office below, a youth named William Taynton, and he rather reluctantly consented to submit himself to the experiment.
>
> I placed him before the transmitter, and went to the next room to see what would appear on the receiving screen. The screen was entirely blank, and no effort of tuning would produce any results. Puzzled and very disappointed, I went back to the transmitter, and there the cause of the failure became at once evident. The boy, scared by the intensely bright light, had backed a yard or so away from the transmitter. I gave him half a crown, and persuaded him that there was no danger, whereupon he took up his position again before the apparatus. This time his head appeared on the receiving screen quite clearly. It is curious to consider that the first person in the world to be televised should have required a bribe to accept the invitation.

Heartened by success, Baird decided to submit his achievement to an expert and critical audience. He issued an invitation to the Royal Institution of Great Britain to visit his attic laboratory and witness a demonstration of the apparatus, which he now named 'the televisor.'

Fifty members of the Institution accepted the invitation, and as the attic could only accommodate six persons at a time, they witnessed the exhibition in relays. The scientists looked on with intense interest as images of living faces were transmitted from one room to the other. The prophecy of fifty years was fulfilled, and 'seeing at a distance' was an accomplished fact.

Dr Russell, F.R.S., the Principal of Faraday House, who witnessed this demonstration, wrote in *Nature*:

> We saw the transmission by television of living human faces, the proper gradation of light and shade, and all the movements of the head, of the lips and mouth, and of a cigarette and its smoke were faithfully portrayed on a screen in a theatre, the transmitter being in a room at the top of the building. Naturally the results are far from perfect. The image cannot be compared with that produced by a good cinematograph film. The likeness, however, was unmistakable, and all the motions are reproduced with absolute fidelity. This is the first time we have seen real television, and, so far as we know, Mr Baird is the first to have accomplished this feat.

It could no longer be doubted that television might become a commercial success; money was forthcoming, and Baird was able to move from the attic in which his experiments had been carried out to larger and more adequately equipped premises near by. Here during 1926 numerous demonstrations were successfully conducted, and the inventor continued his efforts to perfect his apparatus.

Two years later one of the authors took part in an experiment in which his face was transmitted to a receiving set two floors away, before which sat a friend. The rapid progress made by the inventor during those two years will be appreciated when we add that not only was the reproduction of the face sharp and clear, but every movement of the lips came through clearly enough for a lip-reader to have read what was being said. Later, both sides of a one-pound Treasury note were televised and were clearly recognizable.

Even more remarkable, when one remembers that first flickering Maltese cross seen at Hastings in 1923, was the spanning of the Atlantic by television. This was first accomplished in February 1927, when recognizable images of persons were transmitted from London to New York. The signals were sent by land-line from London to the Baird transmitter at Coulsdon, Surrey, and there sent by wireless on 45 metres. They were tuned in at an amateur station at Hartsdale, New York. Commenting upon this demonstration, the *New York Times* said: "His success deserves to rank with Marconi's sending of the letter S across the Atlantic."

Another milestone on the road to television in the home was passed when early the following year Mr Brown, wireless officer of the *Berengaria*, received and recognized the features of his *fiancée* sitting before the transmitter in London, 1500 miles away. The television apparatus was in no way affected by the vibration or rolling of the vessel, and in this demonstration, as in the others we have mentioned, only two operators were engaged, one at each end.

With the success of these varied experiments the problem of television was solved. That the transmission will be further improved is certain, but the secret which men groped after in dozens of laboratories for half a century had been discovered.

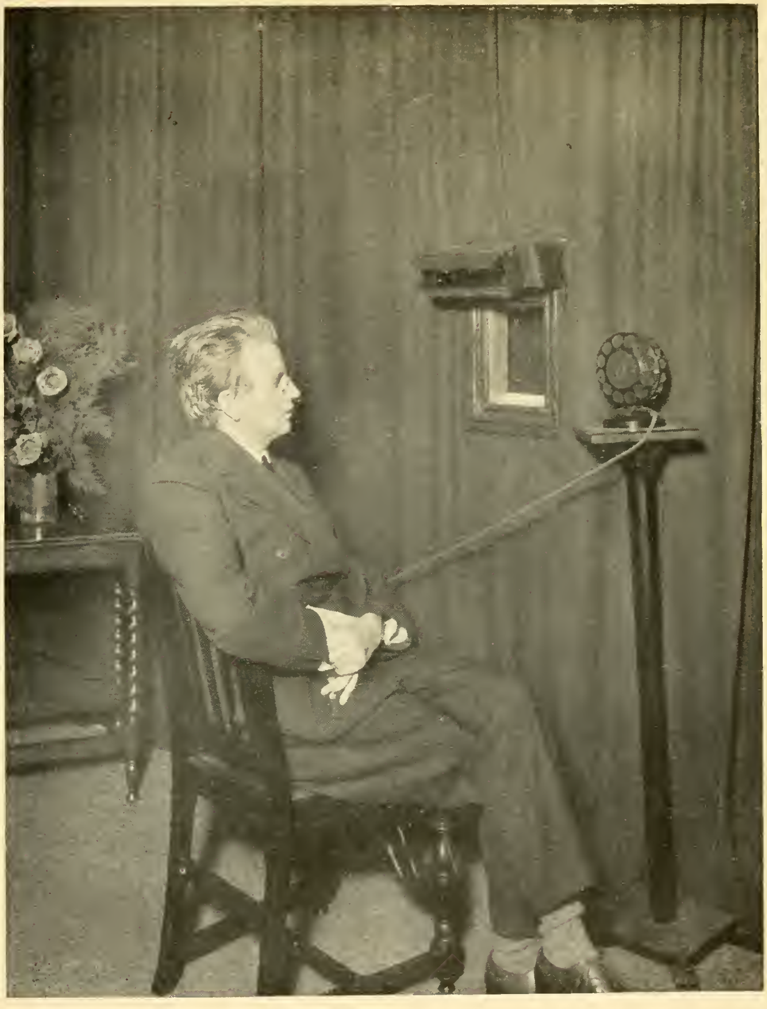
Having told the story of Baird's greatest achievement, we must add a word about the original Baird televisor itself. A detailed description of this earlier apparatus would be too technical to be understood by any but the expert, but the principle behind it is as follows:

The light reflected from the scene to be televised is collected by means of a lens—just as it is when focusing a camera—and this light is focused upon the light-sensitive cell. Interposed between the cell and the lens are three rapidly revolving discs. The first, bearing a number of round lenses in staggered formation, revolves at a rate of 800 revolutions per minute, and breaks up the image into strips. The second is provided with a large number of radial slots and revolves about 4000 times per minute, further cutting up the light-ray. The third disc has a spiral slot and revolves more slowly.

The combined effect of these discs is to cause the whole of the image to fall on the light-sensitive cell in a quick continuous chain of tiny areas of varying brilliance in one-tenth of a second. The light reflected from the shadows is naturally dim, while from the high lights of the scene it is comparatively bright. The cell transforms these rapid variations of light into electric-current variations, which are transmitted to the receiving apparatus by wire or wireless after being amplified.

At the receiver the apparatus is somewhat on the lines of that used at the transmitter, although in a rather simplified form. Similar revolving discs are interposed between the source of light, a glow discharge lamp, and the ground-glass screen. The incoming varying current causes this light to vary in a corresponding manner to the variations of the cell at the transmitter; the discs break up the light and throw it on the screen reconstructing the scene. Considerable modifications of this earlier apparatus have been made in the past year or two.

Since carrying out his first successful television experiments Baird has been devoting part of his time to further developments made possible by his own achievements. The most remarkable of these new developments is noctovision, or seeing in darkness or fog by means of the electric eye of the televisor.



JOHN L. BAIRD SEATED BEFORE THE TRANSMITTER IN HIS LATEST TELEVISION STUDIO

During early experiments in television Baird found that it was essential for his sitters to endure a blinding glare of light if a recognizable image was to be transmitted. He fought to overcome this obvious defect, and later experiments made it possible to televise objects in ordinary daylight. Experimenting further he found that if use was made of the invisible infra-red rays a person sitting before the transmitter could be seen in total darkness. This apparent miracle was achieved through the fact that although the infra-red rays are invisible to the human eye, the sensitive electric eye of the televisor can readily detect them and pick up any image on which they are directed.

Demonstrations of noctovision were given during the British Association meeting at Leeds in September 1927, persons sitting in a dark room in Leeds being clearly seen on the televisor screen in London. More recently the headlights of a motor-car, covered with sheets of ebonite which withheld all except the invisible infra-red rays, were picked up by the noctovisor at night from a distance of three miles, and while the motor-car was quite invisible to the naked eye its progress could be clearly watched on the screen of the noctovisor.

When perfected this further invention will be of great assistance to shipping during fog, for with a noctovisor on the bridge the navigator will be able to pick up the lights of approaching ships or the rays of a lighthouse when through enshrouding fog these are blotted out for every eye save the wonder eye of the Baird apparatus.

Rich as are the records of modern science in men who have triumphed over great obstacles, it is doubtful if any other research-worker of our generation has known a more astounding turn in fortune's wheel than that which brought fame to Baird. His success may be expected shortly not only to give to the world television in the home and all that that miracle means, but also to rob the demon fog of much of its terrors on the high seas.

CHAPTER II

DO PLANTS AND METALS FEEL?

The Amazing Experiments of Sir Jagadis Bose

AS long ago as 1879 a well-known French scientist published a book in which he pointed out that the life of plants has much in common with that of animals. At night, for instance, a green-leaved plant takes in oxygen and gives out carbon dioxide exactly in the same way as you or I or a dog. In fact, the plant breathes.

Again, a plant has digestive ferments which change starch into sugar, and it forms certain waste products, though these it seems able to use up again. Plants have no muscles, yet they have considerable powers of movement. Blossoms turn their open faces toward the sun or lower their heads when rain falls, the tips of twigs are in constant movement, while some plants, such as the sundew, the Venus fly-trap, and the mimosa, have very special movements. The sundew closes its tentacles about the fly caught on its sticky leaf, the fly-trap snaps together the two halves of its trap-shaped leaf-blade, while the mimosa shrinks away from the human hand before it is actually touched, and when touched collapses like a closed umbrella and for the time shams dead.

But it was not until the present century that there appeared a scientist who began a deep study of these phenomena and made the startling discovery that *plants have hearts*. This was Sir Jagadis Chandra Bose, the first Hindu scientist to attain a world-wide reputation, and the first Indian to be knighted for scientific work.

Sir Jagadis Bose is of small stature and is now no longer young, yet one who has heard him lecture says of him that his expression "exhales a spirit of sheer beauty, especially when he talks." He began life as a poor university professor, but his work attracted the attention of Sir James Dewar and Lord Rayleigh, who brought him to England to work in Faraday's laboratory at the Royal Institution.

He worked there to such purpose that even the popular newspapers and magazines recorded the wonders he achieved. Then he went back to India, where he has toiled alone for more than twenty years. Disturbingly alone, for among India's three hundred millions he has been the only man working on these special lines. He has had not a soul in the whole Indian Empire with whom to discuss his ideas and experiments.

In 1926 he was back in England, lecturing before the British Association at Oxford, where the great Einstein himself was in the audience. When the lecture was over Einstein solemnly declared that Bose ought to have a statue erected in his honour in the capital of the League of Nations.

And why was Einstein so impressed? Why is it that Bose's name is now known, not merely in the laboratories, but all over the world? It is because he has proved that all life is one. By actual experiment he has shown that steel and other metals can feel, that plants have emotions, and that everything created lives and dies.

Bose has not done this merely by watching plants through a magnifying glass. He has invented whole sets of delicate instruments for measuring the nervous reflexes of plants. He has been called a mystic, but he is a mystic who measures his visions to the millionth of an inch. He may have the imagination of the East, but to this he adds the cold precision of the Western man of science.

Yet his discoveries are so marvellous that it is difficult to believe them. They seem to be far more like fairy tales than records of scientific fact. Listen to what he says himself:

> Hitherto we have regarded trees and plants as not akin to us because they are the voiceless of the world, but I will show you that they are sensible creatures in that they really exist and can answer your questions. When it receives a shock the leaf of this mimosa drops, and we have invented an apparatus by means of which this answer can be converted into intelligible script. We began by attaching the dropping leaf to a lever, seeking to get the response actually written on paper, but the resistance of movement over paper was too great, so the lever was set to vibrate at one thousand times a second and a musical note was sounded. Now we could measure the effect on the lever to a thousandth part of a heart-beat.
>
> Our hearing ranges through no fewer than eleven octaves, but our sight through only one octave of light. Anything that does not range between red and violet we cannot see. Yet the plant actually sees the ultra-violet and even those ether waves which bring to us wireless concerts.
>
> It is not unlikely that plants have a sixth sense. In certain of my experiments I have noticed—I say it with caution, because I do not want to appear to magnify the truth; that truth exists and we intend to find it—that while a plant was recording a throbbing the pulsing was affected by the approach of certain people, but became normal again when they went away. Generally a plant took twelve minutes to recover from the blow.

The instruments invented by Sir Jagadis for the purpose of measuring the pulses of plants are amazingly delicate. The movements of a plant are so slow that even the sluggish progress of a snail is six thousand times faster than the growth of a plant, whose average rate is one-millionth part of an inch per second. One inch in a million seconds —that is the *average* growth, but some plants, such as the bamboo, grow much more rapidly. A bamboo shoot grows from nine to twelve inches in twenty-four hours.

Sir Jagadis first tried to solve the problem by means of

SIR JAGADIS BOSE

Photo by Elliott and Fry

a delicately poised system of compound levers, but friction of contact at the bearings limited magnification to ten thousand times, which was not sufficient for his purpose. Then he tried a single magnetic lever, which by its movement rotated a delicately poised astatic needle (a needle which is unaffected by the earth's rotation). A spot of light reflected on a screen from a tiny mirror attached to the needle gave a magnification which could be increased from a million to a hundred million times. This magnified the highest power of a microscope no less than one hundred thousand times. He called this machine the crescograph (growth-recording machine), and some idea of its power may be gathered from the fact that if attached to a snail it would show this slowest of creatures as shooting forward at the rate of two hundred million feet an hour. Sir Jagadis says:

> Plants have hearts. Long before I invented the crescograph I was already certain that sap-pressure rising in the stem worked in almost exactly the same way as blood driven by the human heart. In other words the pressure was not constant, but came in beats. The crescograph gave definite proof that every surmise was correct. The actual rate of the pulsation of sap in a cyclamen proved to be the one-hundred-thousandth part of an inch per second, but when the leaf was placed on the magnetic needle of the instrument the spot of light curved to and fro on the screen at the rate of ten feet in twelve seconds.

Another method employed by the great Indian scientist was one in which he pushed an electrical probe against the stem of the plant, shifting the probe forward by one-tenth of a millimetre at a time until the galvanometer began to record. His aim was to keep the stem stationary, allowing the rod to touch the stem with just the right pressure, so that each heart-beat could be discovered. The great difficulty was to find the right kind of rod; many things were tried, but proved useless. One day Sir Jagadis was at the Zoo, and happened to pick up the quill of a hedgehog. In a flash he realized that this was an ideal rod, as indeed it proved to be.

Another problem was to keep the very delicate instrument from being affected by the shaking caused by lorries and other heavy vehicles passing over the road outside the house. Complicated shock-absorbers had to be devised and constructed before this object was attained.

The Bose Institute is near Calcutta; there is a lecture theatre and a laboratory surrounded by a charming garden. Around the garden are the quarters of European and Indian students. Not so much as a screw comes from outside. Everything for the delicate instruments is made there in the workshops. There is plenty of money available, for although Sir Jagadis has troubled little about patent rights of his inventions, he has done so many marvellous things that he has made a large fortune—how large may be gathered from the fact that he has endowed his institute with a sum of one hundred thousand pounds; and although he lives like a hermit and gives away almost all his income, yet fresh sums are always coming in from all parts of the world.

His instruments are so marvellously delicate that he has been able to prove that plants respond to wireless stimulation which is beyond the limit of human perception. Here is an instance of his methods. He takes a mimosa (the sensitive plant already mentioned) and brings this up under glass, screened from all shock and discomfort. To all appearance it flourishes and grows fat, yet when tested it proves sluggish. It no longer responds, like its wild brother, to stimulation. A graph of its slow movements is taken; these provide a startling contrast to the complete collapse of the wild mimosa.

Then Sir Jagadis poisons a plant, placing the stem in bromide, and the plant is made to inscribe the throbbing pulsations due to the action of the poison. The result suggests the flutterings of a living creature struggling for life.

Thousands of years ago Indian doctors discovered that a very small amount of the poison from the fangs of a cobra administered in the form of a solution had the effect of reviving dying patients. This explains why it has been the custom to take the body of an Indian who has died from cobra bite and to place it on a raft and send it downstream, the idea being that he may later wake up. Sir Jagadis has discovered that this solution of cobra poison will quicken the heart-beats of a plant.

The human tongue is very sensitive to electric currents, and in this respect a Hindu is on an average twice as sensitive as a European. It has been found by experiment that different individuals and different races vary enormously in their response to such stimuli as electric currents, as also in their response to changes of temperature, of pressure, and of light. Some people can hear the high-pitched squeak of the bat, others cannot; some are intensely sensitive to draughts, others get a headache before a thunderstorm. The ant perceives the rays beyond the violet which are invisible to man, and many birds seem to have a magnetic sense which guides them on long flights out of sight of land.

In the same way plants are found to vary greatly in their powers of perception. Sir Jagadis has shown, for instance, that a tree can notice the passing of a cloud between itself and the sun. With his delicate instruments he has proved that it reacts—you might almost say 'shivers.' And plants are far more sensitive to electric currents than man. The biophytum, for instance, has been proved to be eight times more sensitive than even the most sensitive human tongue.

On the other hand, plants are slower in their response to such stimuli. In man or other animals there is an appreciable time between the spur and the reaction. If you prick your foot with a needle the message of pain has to be flashed from the foot to the brain and back by means of a chain of nerves. In a frog this interval is about one-hundredth of a second, but in a plant it is fifty to seventy-five times as long, and the interval is longer in cold weather than in warm. It is also lengthened by fatigue. In other words, if you try the same experiment several times on the same plant the plant gets tired and the latent period—as it is called—grows longer and longer. Sir Jagadis considers that the line of cells along which the impulse passes in a plant resembles the human nerves, and that the plant begins to show traces of mind.

There is a practical result from all this work, for Sir Jagadis has discovered a large number of plants which have medicinal properties, the existence of which had never before been suspected. Some of these are especially useful in cases of failing heart action.

Sir Jagadis has done much more than enlarge our knowledge of plants. He has worked on metals and discovered that they too have the vital force. Metal-workers have known for a long time past that metals can suffer from fatigue. For that matter, every man who owns razors knows that it is not good to use the same blade day after day. A razor in daily use gets duller and duller, even if stropped afresh at each time of using; but if it be laid aside for a few days it will recover its keen edge. The X-ray has demonstrated that rest causes the disturbed molecules to fall back into their original positions.

Sir Jagadis uses the galvanometer to test the fatigue of metals. The galvanometer is a delicate instrument used for detecting the presence of electric currents. It contains a needle on a pivot, and this needle is deflected by even the faintest of currents. Diagrams from galvanometer tests show that metal resembles muscle in that its sensitiveness grows less and less under repeated stimulation.

But Sir Jagadis has gone farther than this. We all know the effect of great cold on our own bodies, which grow numb. If your hand is half-frozen you may cut it badly without feeling the pain. Then as regards animals, creatures such as hedgehogs lie all the winter in a sleep that resembles death. Sir Jagadis has proved that metals, like animals, are most sensitive at temperatures characteristic of summer, while in frost or in great heat their sensitiveness rapidly diminishes. More wonderful still, he has shown that metals are affected by stimulants and by narcotics. A dose of bromide puts the human brain to sleep and a dose of bromide of potassium administered to a block of tin makes it lose much of its normal sensitiveness.

The parallel between man and metals has been carried even farther. A large dose of opium deadens all the human senses, but a small dose makes them more active. Metals react in a corresponding way.

More marvellous still, metals can be killed by poison, like animals. A piece of metal in a healthy condition was taken and tested; the galvanometer showed that it was in full vigour. Then it was treated with a dose of oxalic acid, a strong poison. At once there was a spasmodic flutter, then the galvanometer signals grew more and more feeble, until they almost ceased. A powerful antidote was applied, and slowly the metal began to recover and to record again. The metal was given a rest, and soon recovered its normal activity.

Then the experiment was carried out a second time, the metal being kept in the bath of poison until the signals ceased altogether. The metal was then taken out and the antidote applied. It was too late. The metal had been killed. Sir Jagadis varied the experiment by using other metals, but in each case the result was the same.

This is a very strange thing, for apparently, of course, the poison affects only the outside of the metal, by rusting it. Yet actually the entire molecular structure of the metal is affected. It appears that the metals we use in our knives, pens, motor-cars, and so forth are dead, or at least in a state of coma caused by the enormous temperatures and the pounding which they have suffered. But the foregoing experiments make it conceivable that in future we may make use of live metals in ways as yet untried.

Sir Jagadis ranks as one of the most original of scientific explorers, for he is the first to prove that the three kingdoms of matter—the animal, the vegetable, and the mineral—are one in essence, and that the distinction previously drawn between organic and inorganic matter is based on a false assumption.

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CHAPTER III

SOME X-RAY MIRACLES

Sir William Bragg and his 'Jolly' Occupations

NOT so many years ago the atom was looked upon as a hard little particle, the brick with which matter was built up. Then came doubts on the subject, and more doubts, until the solid atom as thought of in Victorian times was proved by Rutherford and others to be a number of tiny specks floating or revolving in void. Professor Eddington says that Einstein and Rutherford are the 'villains of the piece,' but what about Bragg, who proved that one atom could go right through another?

The atom, as we now know it, resembles a planetary system with satellites revolving around a central sun. Now the planets of our own system are so far apart—the new planet is no less than four thousand million miles away from the sun—that it is quite possible to imagine a second planetary system passing through ours without any collision occurring between the various members of the two systems. And that, in fact, seems to be exactly what happens when two atoms meet. Unless there is a collision between the protons, the inconceivably small centres of the atoms—and the chance is about a million to one against it—the two atoms pass through one another without damage to their constituent parts.

That has been proved—definitely proved—in a famous experiment carried out by Sir William Bragg, who made an atom of helium take a perfectly straight path through an inch of air. An inch does not seem much, yet it is a huge journey when considered in terms of atoms, a journey during which the helium atom must have passed through many millions of other atoms.

" You cannot force one billiard ball through another," says Sir William. " The moving ball either pushes the still ball in front of it, or both move away at different angles." Now the helium atom could not push millions of other atoms before it, yet its course was dead straight. Thus it must have gone through the other atoms, and so we have definite and conclusive proof that an atom is not a solid body and that two atoms can occupy the same space.

Mr C. P. R. Wilson, who has worked much with Sir William Bragg, emphasized this fact when he passed an *alpha* particle (the smallest particle known) through damp air, and succeeded in photographing the tiny trail of mist or fog which it left behind it in its extremely rapid passage.

Sir William's chief work has been the exploration of the X-ray. In 1908, when Sir William became Cavendish Professor at Leeds University, the X-ray was in constant use in surgery, yet there was still much doubt as to the actual working of these rays. In other words, the people who used the rays had very little idea as to how they worked and why they penetrated solid bodies. This was the task Sir William set himself; he resolved to find out exactly what happened, and in a long course of experiments he proved that X-rays themselves do nothing to the matter through which they pass. What actually happens is that they produce a comparatively small number of fast-moving *beta* particles which start off at great speed, and it is these electrons which do the work. " They may," said Sir William, " be compared to stones which on the level remain at rest, but when started down hill become extremely active."

In the course of his experiments Sir William made the interesting discovery that X-rays, which had been

SIR WILLIAM BRAGG GIVES A SCIENTIFIC DEMONSTRATION TO AN APPRECIATIVE AUDIENCE

regarded as particles, had also the properties of waves. Considerably puzzled, he called in his son, William Lawrence Bragg, then little more than twenty years of age, and one result of their researches was that in 1915 they were jointly awarded the Nobel Prize for Physics. The story of these interesting experiments is told in Sir William Bragg's book *An Introduction to Crystal Analysis* (Bell, 1928).

The book begins with the account of an experiment made by M. Laue in the year 1912, which proved that X-rays were of the same nature as rays of light. M. Laue passed a fine pencil of X-rays through a crystal of the precious stone called beryl and allowed it to fall on a photographic plate. After an exposure the plate was developed, and the result was a most exquisite pattern resembling a great flower.

The experiment was a complete success, and gave convincing proof that X-rays are of the same nature as rays of light; also it opened out a new field of research, which has proved to be of the greatest practical value to industry. The explanation is that it gave chemists a new method of investigating the structure of solid bodies. Hitherto this kind of examination had been confined to liquids and gases, but with the aid of the X-ray and the camera chemists were at last able to explore solids, and during the past eighteen years these researches have been extended to all kinds of objects, such as wool fibre, silk, metals, wood, rubber, etc.

As Sir William said in one of his Christmas lectures, we are now able to look ten thousand times deeper into the structure of the matter that makes up our universe than we were able to look when we had to depend on the microscope alone. The discoveries of radio-activity and of X-rays have given us new eyes, so that we can understand many things that formerly were obscure.

The chemistry of any solid body depends upon the arrangement of the molecules of which it is composed, and examination by means of X-ray spectroscopy discloses the arrangement of the molecules. When a steel-founder produces a steel ingot he has changed the structure of the iron as originally smelted by adding a certain proportion of carbon atoms to the atoms of iron. Now the microscope can show the existence of separate crystals in a metal, but not the arrangement of atoms in a crystal. That is where the X-ray comes in, and already it has thrown a flood of light upon the inner meaning and purpose of all the complex properties of metals.

All through the centuries metal-workers have worked by rule of thumb, experimenting more or less blindly, occasionally with profit, but more often failing. Now with the aid of the X-ray they are beginning to work with some degree of certainty, and have already discovered many interesting secrets. For instance, it is known that the properties of metals depend on the variety of crystalline structure. Under pressure some sets of atoms in crystals tend to slip over other sets. A fairly thick sheet of aluminium, if composed of a single crystal, can be bent in a man's hand, yet an ordinary piece of the same metal is quite stiff. In this latter piece the crystals are pointing in all directions, so that some are always ready to take the strain.

A metal usually becomes harder when beaten. This has been known to metal-workers for thousands of years. A bronze sword dug up in Shropshire had edges almost as hard as steel, and it was found that the sword had been hardened by beating while it was cold, being tempered afterward to remove the brittleness. The man who made that sword had no idea, of course, why beating hardened his metal. It is the X-ray that has shown us how the beating rearranges the crystals.

Bronze was the first of the alloys. It is made of copper and tin; both are soft metals, yet a compound of the two is harder than iron. This is the age of alloys, and one important modern alloy is a mixture of aluminium and copper. A very small amount of the former metal added to copper hardens it greatly, and the X-rays show us that when aluminium is added the structure of the copper crystals remains the same, but that here and there an aluminium atom takes the place of a copper atom. This prevents slipping and causes the hardness. But there must not be more than ten per cent. of aluminium in the mixture. If more than ten per cent. is used the copper crystals are broken up altogether and a new structure is formed.

All this may seem a little technical, but it is difficult to put it more simply, and it is important because it is yet another proof of the value of Science to industry. Thanks to the researches of Sir William Bragg and his followers, metal-workers are now able to compound their alloys on a definite scientific basis, instead of working blindly as before.

We have spoken of the result of the first experiment made by M. Laue—explaining that the pattern shown by the photograph was very beautiful in shape and perfectly symmetrical. Similar results have been obtained in all photographs taken under similar conditions, thus emphasizing the fact that Nature always tries to arrange things regularly.

Take an X-ray picture of a section of fine-drawn aluminium wire, no thicker than a hair, and you have a black circle with a white centre. Around this centre there are rays, then two broken circles (broken, however, with perfect regularity), and near the rim two more kindred circles. The whole is like a burnished convex shield of great beauty.

The X-ray photograph of a section of a thin cord of rubber resembles the sun in eclipse with a dark corona around it; rock salt gives a dark centre with an intricate but perfectly regular pattern of dots arranged about it. It does not matter what subject you choose, the result is a pattern more or less intricate, yet perfectly regular, and often astonishingly beautiful.

The manufacture of artificial silk grows by leaps and bounds. This of course is made of cellulose blown out into fibres so fine that they match the thinness of the silkworm's own product. The holes through which the liquid viscose is forced are one-five-thousandth of an inch in diameter. These threads are constantly examined and analysed by the X-ray, and for much of the beauty and cheapness of the stockings they wear now women are indebted to the experiments made by scientists such as Sir William Bragg and M. Laue.

Similarly we are indebted in some measure to the X-ray for our cheap and reliable electric bulbs. In the laboratory of the General Electric Company at Wembley the fine wire filaments are examined under the X-ray, and from enlarged photographs of the extremely fine wires used the chemists learn more about the composition of the metal than they could in any other way.

The needle of a compass is hung upon a tiny jewel, and similar jewels are used in the making of all high-class watches, such as you see advertised as being jewelled in so many holes. Here again the X-ray photograph plays its part, enabling the cutter to make perfect his delicate work, and to see with ease whether the tiny crystal of sapphire, or whatever it may be, is of the requisite quality.

No industry owes more to scientific research than the motor-car industry. Those who drove motor-cars twenty years ago will remember that one of the greatest difficulties in those days was the weakness of the tyres; punctures were distressingly frequent, and it was not unusual for a tyre to burst. For the infinitely more reliable tyre of to-day we are indebted partly to the X-ray.

A startling discovery made through these X-ray methods is that of the exact size of the carbon atoms in the diamond. (Every boy knows that the hardest of precious stones is made of the same material as charcoal or graphite.) It has been found that the atoms of carbon in the diamond are each 1·54 hundred-millionths of a centimetre in diameter. Each carbon atom in the diamond is at the centre of gravity of four others. These four lie at the corners of a four-cornered pyramid, and the first carbon atom is at the same distance from each of the others. In this simplicity and regularity of structure we have the secret of the intense hardness of the diamond.

Carbon atoms generally arrange themselves in long chains which are the skeleton structure of fats and oils, or else in rings each containing six atoms. In graphite (blacklead) these rings lie in flakes which slip over one another very easily. That is why a lead pencil writes so easily and why graphite is such a good lubricant.

Carbon atoms are the basis of dyes, explosives, and many drugs, as well as of foods and fuels, and of our own bodies. X-ray photography is of the greatest value in the investigation of substances such as naphthaline and anthracene, which are of the first importance in the dye industry.

It is Sir William Bragg's opinion that we may one day be able to go far beyond our present level of investigation and that by the development of X-rays we may be able to see many thousand times farther than we can see to-day. But this goal will not be attained without hard work. In the Royal Institution, where Sir William kindly gave an interview to the author of this chapter, the work goes on steadily, special apparatus having been built for it.

It was in 1923 that Sir William became Director of the Royal Institution, the most famous of the learned societies of Great Britain. It corresponds to the Académie of France and the Lincei of Italy. It is a scientific club with a very large membership, and is housed in a fine building at the top of Albemarle Street, Piccadilly.

The lecture-theatre is well known to schoolboys because of the Christmas lectures given there. In 1929 this theatre was pulled down, and it is now being rebuilt.

The Royal Institution was founded in 1799 by Benjamin Thompson, Count von Rumford, who wrote a pamphlet entitled: *Proposals for forming by Subscription in the Metropolis of the British Empire a Public Institution for diffusing the Knowledge and facilitating the General Introduction of Useful Mechanical Inventions and Improvements, and for teaching by Course of Philosophical Lectures and Experiments the Application of Science to the Common Purposes of Life.*

Count von Rumford's idea was to bring Science and Art closer together, to have a place where scientists and people engaged in manufactures could meet, and where they might join in improving farming, commerce, and comfort in the home. What was in his mind was the idea of a great central school of Science combined with an institute of engineering. He suggested that there should be models of such things as fireplaces, kitchen utensils, laundry appliances, brewers' boilers, distillers' coppers, limekilns, spinning-wheels, and all sorts of ploughs and farming implements.

He suggested lectures on such subjects as the management of domestic fires, preserving ice for summer use, the tanning of leather, and many other useful and practical subjects. His ideas were so well received that at the first meeting, presided over by Sir Joseph Banks, he had fifty subscribers of fifty guineas each, and it was decided that the annual subscription should be two guineas. A house was taken in Albemarle Street, and in 1800 the Institution received a Royal Charter.

The first lecturer was the famous Sir Humphry Davy, who was also made Director of the Laboratory. He had a room in the house and a salary of a hundred guineas a year.

The Institution fell on hard times; the subscriptions that had totalled eleven thousand pounds in 1800 dropped to three thousand pounds in 1802. It seemed that the whole establishment was going to pieces, but Davy came to the rescue. He gave a lecture in which he stated the reasons for the existence of the Institution, and stated them so brilliantly that every one began to talk of the Institution and its work. His lectures were printed and read everywhere, subscriptions poured in, and the Institution was saved. But von Rumford was offended; he left London and never returned. After that the industrial element declined and the Institution became more and more the home of Science. Professors carried out their researches in the laboratories, and lectures were given on Art as well as on Science.

Davy worked very hard. He would come at ten or eleven in the morning and sometimes stay till four the next morning. His lectures always attracted crowds, and it is a proof of his popularity that when he fell ill in 1808 receipts fell from four thousand to fifteen hundred pounds. It was Davy who gave Michael Faraday his start. Faraday was a young bookseller who listened to Davy's lectures and made notes. He sent the notes to Sir Humphry, who wrote him a courteous reply and after interviewing him gave him a post as assistant in the laboratory. In 1825 Faraday first lectured on those electro-magnetic experiments which have made him famous; in 1835 he was given a Civil List pension of three hundred pounds, and in 1864 he was offered, but declined, the Presidency of the Royal Institution.

Another great lecturer in Albemarle Street was John Tyndall, who became Superintendent after the death of

Faraday. It was after Tyndall's death that Lord Rayleigh became Professor of Natural Philosophy.

We have written about Sir William Bragg's discoveries and about the great Institution over which he presides, but as yet have written nothing about Sir William himself.

The story of Sir William's scientific career begins a great many years ago, on an occasion when two young men were walking together in Cambridge. One was William Bragg, Third Wrangler, just ready to leave the university, the other was J. J. Thomson. Thomson asked Bragg if he had seen that there was an opening for a Science lectureship in Adelaide University in Australia, and suggested that he might try for the post.

Bragg at once made inquiries, found that the very last day for entries had been reached, and so wired his application. Shortly afterward he was sent for and interviewed by an Australian gentleman, who told him presently that he was the chosen candidate. This gentleman was Sir Charles Todd, who gained world fame by driving the great trans-continental telegraph line across the waterless desert of Central Australia. His daughter afterward became Lady Bragg.

At Adelaide young Bragg found a small but well-equipped laboratory, and it was there that he began his researches. After spending many years in Adelaide, Bragg was recalled to England to take up the position at Leeds University to which we have already referred. As well as the Nobel Prize, Sir William has received the Barnard Gold Medal of Columbia University, the Rumford Medal of the Royal Society, and many other distinctions.

Sir William makes Science seem easy; he expresses his thoughts in simple language, and for this reason his Christmas lectures to young folk have always been popular. He says that scientific research and experiment are

' jolly ' occupations—that one is always finding something out and that there is no crossword puzzle which can rival in interest the practical working out of a puzzle in chemistry. He likes to see younger people keen on Science, because the future of the nation depends to such an extent on scientific efficiency. But he gives this word of warning: " It would be a mistake to suppose that because scientific work is jolly it is therefore easy. Much hard work has to be done before there is any ease about it."

CHAPTER IV

THE WIZARD OF THE GARDEN

The Story of Luther Burbank

WHY does a thistle grow spines? Why do so many plants put out sharp spikes and crooked thorns? The answer is simple. The thorns are put out simply for the purpose of protecting the plant from animals that would otherwise devour it. Says Luther Burbank:

> If we invite Mr Thistle or Mr Cactus into our garden and patiently and earnestly convince him that all marauding animals will be kept out it will not be very long before some member of his tribe will see fit partly to discard some of these exasperating pins and needles and put on a more civilized suit of clothes. By careful selection from this one varying individual others will be produced which will be absolutely spineless, to remain so as long as the marauders do not disturb them.

Here in a few sentences you have the first secret of the plant wizard, Luther Burbank, a man to whom every gardener, every grower of fruit and flowers and vegetables, owes a great debt, just as every grower of wheat owes a similar debt to the English Garton brothers for their improvements in cereals. That secret is selection.

We propose to explain what is meant by selection and to tell of the other methods by which this wonderful man attained his remarkable results, but first we will explain why we choose Luther Burbank out of many similar geniuses as a typical hero of modern science.

Luther Burbank was born in Lancaster, in the state of Massachusetts, in the year 1849, and was the thirteenth of fifteen children. People talk of thirteen as an unlucky number, and certainly Luther had his share of ill-luck. It was plain from the very first that he was a plant-lover. When he was only three years old he made a pet of a little cactus plant in a pot, and carried it everywhere with him. When one day he, plant in hand, got knocked down, the pot broken, and the earth scattered, he wept bitterly, yet at once set to work to re-pot and mend the poor broken little plant. It is an interesting coincidence that one of his biggest works in later life had to do with the cactus family.

He was born a gardener, but his parents put him into an engineering-shop in which his uncle was interested, and where the boy worked to the best of his ability. Whatever his job Luther always did his best. Luckily for the boy, this uncle had a garden and a greenhouse, and on half-holidays Luther was allowed to work among the plants. He used to thin out carefully the bunches of grapes, and he raised a number of grape seedlings. So he carried on until when he was sixteen he brought to his uncle an invention for improving a machine in the factory, an invention so valuable that the owners of the factory offered him a big salary if he would devote all his time to similar inventions. The boy did not hesitate.

" It's plants I love," he said, " not machinery. The one thing I want to do is have a nursery garden of my own."

The owners and Luther's uncle were much disappointed, but the lad's mind was made up, and his uncle, seeing how keen he was, promised that he would not oppose his wish. The result was that before he was twenty years old young Burbank was owner and manager of a small nursery garden. He got his capital—part of it, at any rate—by the sale of a new variety of potato which he had grown in his uncle's garden from seed.

The nursery garden grew and expanded rapidly.

Within five years the profits were five thousand dollars a year, and before long they had risen to ten. All his spare time the young man devoted to raising better varieties of ordinary plants, and his nursery soon became famous for its magnificent potatoes. Profits went up until they reached four thousand pounds a year, but nearly all these profits were spent by Burbank on various experiments.

In the year 1893 Burbank startled his friends in Massachusetts by suddenly selling out his big and flourishing business. It had long been in his mind that this Northern climate, with its long, cold winter, was not the best for his experiments, and after a visit to California he decided that the soil and climate of that state promised far greater opportunities. He made up his mind to start a new business at Santa Rosa, and there he went with a small stock of his already famous Burbank potatoes, but without more money than was sufficient to buy a few acres of land.

He found California ideal for the raising of new varieties, and plunged into his work with tremendous energy. Too much energy, for he became so keen on producing new sorts of fruits, flowers, and vegetables that he neglected the paying side of the business, so that before long he became very short of money. It takes years to produce new varieties of plants, and sometimes these years are wasted and the expectations of the grower are not realized. Like most geniuses, Luther Burbank now had a very bad time. He said :

> I have known what it is to feel the pangs of hunger, I have slept in noisome places when I could call no roof my own ; I have done the most repugnant and disagreeable work so as to earn a pittance to keep body and soul together ; I have fought off fever when I had not the money to pay for a daily pint of milk which stood between me and possible death ; I have denied myself all the minor luxuries of life and most of its comforts, while for years I did not even own a microscope, so important and indispensable an instrument in my work.

LUTHER BURBANK AMONG HIS FLOWERS

Worse than the sufferings of his body were those of his mind. His neighbours, who saw him raising thousands of plants and then consigning all, or nearly all, to a bonfire, thought he was crazy. He was held in derision by his relatives, in pity by his friends. Scientific men denounced him as a charlatan, a producer of spectacular effects, a seeker for the uncanny, a misleading prophet. One clergyman actually preached against him, calling him a "foe to God." Remember, please, that Luther Burbank was no longer a young man, that his health was broken, and that he had so little money that he could never afford to hire the labour he needed or buy the fertilizers. Often he could hardly pay the taxes on the land. Yet he never lost heart, and year after year he toiled away, growing thousands of new plants of one particular sort at a time, testing them, then ruthlessly destroying all those that failed to come up to his expectations.

In the production of one of his most famous fruits, the well-known Primus berry, which is a cross between the blackberry of California and the raspberry of Siberia, he secured five thousand seedlings from the many crosses made, and though the fruits of some of these were marvellous in appearance, not one was found to be of any commercial value, and all the plants were grubbed up and destroyed. No fewer than nine hundred thousand berry-bushes, mostly two years old, were grubbed up and burned in a single season because Burbank did not consider them fit to live.

It was not until the year 1899 that the genius of this great man was first recognized. In that year the Association of American Agricultural Colleges met in San Francisco, and a number of the representatives paid a visit to the Burbank Gardens at Santa Rosa and his farm at Sebastopol, where they saw his new sorts of potatoes, plums, nuts, and grapes, and were immensely interested. Within a few days accounts of this visit, with photographs, appeared in scores of different papers all over the country, and in a month the plant wizard was famous.

Now what a change came over the scene! Visitors began to pour in, and letters in amazing numbers. Three years later more than six thousand visitors, many coming from the farthest points of the earth, visited the gardens at Santa Rosa, and the number of letters received sometimes exceeded three hundred a day. Better still, the Carnegie Institute recognized the work of Luther Burbank and voted him a sum of two thousand pounds a year for ten years to help him carry out his experiments.

Now let us turn to the fascinating world of wonders which Burbank's patient experiments have opened up to the world of farming and gardening, and also to those who like good fruits for dessert.

As we have said, his first novelty was the Burbank potato, which he produced long before he went to California. He got it by hybridizing the flower of one potato with pollen from another and growing potatoes from the seed so produced. This is a long and tedious process, for in the first season potatoes produced from seed are little larger than peas, and it takes three years to raise them to marketable size. The Burbank potato is beautifully white and so productive that it is reckoned it has added a value of no less than three and a half million sterling to the yearly production of potatoes in North America.

Next came the Burbank plum, a large, handsome, luscious fruit which was so different from other plums that at first the growers, canners, and shippers would have nothing of it. It is now nearly forty years since it first came into being, and it is grown more widely than any other plum in North America.

Not content with merely producing new varieties, Burbank went on to cross different fruits, and presently produced what he called a ‘plumcot.’ This is a combination of the American wild plum, a Japanese plum, and the common apricot. It is hardy like the wild plum, has a delicious flavour, and its flesh is firm so that it will stand packing and travelling.

Plums were always a favourite subject for Burbank's experiments. He was successful in producing a number that had no stones, and others with stones so soft they could be cut in two with a knife, but his greatest triumph in this line was a new prune four times the size of the French prune—from which it sprang—and very much richer in sugar. Fifty years ago France supplied prunes to almost the whole world, but to-day, thanks to Burbank, California has an enormous trade in this particular commodity. Another plum that Burbank created has the flavour of a pear.

At one time there were growing in the garden at Santa Rosa three hundred thousand distinct varieties of plums, differing one from another in foliage, in form and colour of fruit, in flavour, and in all other qualities, sixty thousand peaches and nectarines, between five and six thousand almonds, two thousand cherries, two thousand pears, one thousand grapes, three thousand apples, twelve hundred quinces, five thousand walnuts, five thousand chestnuts, between five and six thousand berries of all descriptions, and many thousands of other fruits and flowers and vegetables.

‘ Colossal ’ is the only word to apply to such an enterprise, and one wonders how any one individual could possibly handle such a business. For it must be remembered that each one of all these thousands of trees and vines had to be watched by Burbank himself, its habit of growth, size, shape and flavour of fruit produced carefully observed. Yet the skill of the man was such that the task was never beyond him, and a visitor who watched him at work wrote of him:

> With aids to bring him the plants, he passes them on with such rapidity that a hundred thousand may be decided on in a single day. If all these plants had to be tested in the usual way each would have to be set out by itself, each would have to be cultivated and cared for for four or five years, each would need to be grafted. In a single day this one man accomplished what could be reached otherwise only by years of waiting and by an enormous attendant expense. . . . As the plants [plum seedlings] came before him they were instantly separated into three classes, good, mediocre, and worthless. Then all were planted to decide the matter, and when they produced fruit it was found that Burbank's verdict had been right in every single case.

To Burbank, as he once said, plants had faces, and he read them as easily as the head of a big business reads the faces of his clerks and workmen. His judgment was severe, for no plant that had not real quality or beauty was allowed to survive, and every autumn the smoke from many bonfires drifted across his gardens.

Many of the achievements of Luther Burbank savour so strongly of the miraculous that if he had lived three centuries earlier he would probably have been burned at the stake as a wizard. Take, for instance, his work on the cactus. As we all know, the cactus is a desert plant. There are many different varieties, but all are marked by thick, fleshy leaves covered with the most deadly thorns, by brilliant blossoms, while many bear a fruit which is quite eatable, but, like the rest of the plant, covered thickly with needle-like spines. The cacti thrive in sandy, stony, waterless deserts where no other plant except spinifex or mulga can take hold.

Burbank began by taking away the thorns. In his tamed cacti not one remains. He then took away the hard, woody substance of the leaves, so that these juicy leaves became good forage for oxen, horses, or mules. He proceeded to breed the fruit to a perfection never before dreamed of. Those who have eaten it say that it has a mixed flavour of peach, melon, and pineapple. A single Burbank cactus plant three years old produced six hundred pounds of food, for the leaves candied like lemon rind or ginger were found to be delicious, or they could be boiled to provide a vegetable.

Burbank has taken roses, blackberries, and gooseberries and induced all these plants to shed their thorns. At the same time he has improved their fruits both in size and flavour. He has created a white blackberry that is large, luscious in flavour, and beautiful to look at. It is completely thornless. You can rub the stalk against your cheek and find it smooth as velvet.

His experiments with the poppy were amazing. He took the common garden poppy, which is an annual, crossed it with the Oriental poppy, which is a perennial, and produced a new race of poppies of wondrous beauty and size. In the course of this work he had at one time in his garden two thousand poppy plants not merely unlike in colour and habit of growth, but resembling in form and foliage nearly every order of plant known. The perfect poppy which he eventually evolved had a bloom ten inches across.

The useful walnut has one disadvantage in that it is a very slow-growing tree. Burbank created a new walnut which, at thirteen years old, was six times the size of the average twenty-eight-year-old walnut-tree. He tackled the Spanish chestnut, and produced a dwarf tree which began to bear a crop of nuts at eighteen months old and when it was only three feet high.

He turned his attention to that common inhabitant of all gardens, the rhubarb plant. Rhubarb, as every gardener knows, is only fit for use in spring and early summer, but Burbank has grown a rhubarb which yields every day in the year and whose stalks are of excellent quality. Its size may be judged from the fact that the leaves average four feet in length by three across. This rhubarb had as its original parent a wild Australian rhubarb. It has been extensively grown in America and Great Britain, and one of Burbank's customers for this plant was the late King Edward.

One of the strangest things Burbank ever did was to take the odour out of onions. We all know that many cooks cannot handle onions because they make tears stream from their eyes. The California wizard went to work and in five years produced an absolutely odourless onion, which was large, tender, and wholesome. But most of us are so wedded to the old strong-smelling type of bulb that this particular novelty had little success.

In the realm of flowers Burbank produced many new things. One is a new gladiolus, called the California, which blooms all round the stalk like a hyacinth. He experimented with the arum or calla lily and produced a miniature form of this exquisite bloom which is less than an inch in diameter. Perhaps the best known of all his new flowers is the Shasta daisy, one parent of which is the common field daisy. Yet the Shasta is a beautiful giant with a magnificent bloom from five to seven inches in diameter. Another of his triumphs is a monster amaryllis with blooms ten inches in diameter, bright with the most glorious colours.

Some one visiting his gardens once said to him: "Mr Burbank, you do marvels in changing shape, colour, and size of flowers, but could you take a flower with an unpleasant odour and make it sweet-smelling?"

The wizard smiled. "I might try," he said. He did try. He took the dahlia, that handsomest of autumn flowers, but having an odour which to most people is somewhat offensive, and within a few years changed it so that its showy blooms were almost as sweet as those of the clove carnation.

There does not seem to be anything that this amazing man would not try, and little that he was unable to do.

We have spoken of his swiftly growing walnut, but he did more with the walnut than increase its speed of growth. He created one with a thinner shell. So thin was the shell that he found the marauding birds were able to drive their beaks through it and extract the kernel. This would not do, so he reversed the process and bred back until he had a nut of just the right shell-thickness.

He crossed peaches and nectarines and made the resulting tree yield fruit earlier than either of its parents. He produced nectarines with yellow flesh and rich scarlet skins which are said to be the most beautiful and perfect in flavour of all the peach tribe. In all, Luther Burbank produced more than two thousand entirely new varieties of fruit, flowers, and vegetables, an advance without parallel in the history of gardening.

And how, you will ask, were these wonders brought about? Very simply. A watchglass and a camel's-hair brush were his principal instruments, these being used to remove pollen from one bloom and insert it into another. For the rest, genius and patience.

"All my triumphs," he said himself, "have been gained by carefully and patiently observing the laws of nature and by experiment." Selection combined with breeding explains the secret of his success.

To begin with, he might breed together two separate flowers in order to create what may be called a working basis, sprinkling the pollen of one flower on the stigma of another. The two plants might come, one from South America, the other from Mongolia. Each plant had its characteristics, its habits, its structure, its hereditary tendencies, its own special life distinct from others, and this identity the plant had preserved for thousands of years. United, the two plants between them produced seed, which was planted and grew.

From these seeds might come plants resembling one of its ancestors or very different from either. Sometimes there appeared a whole series of monstrosities unlike anything that ever before had grown from the earth. But among all these freaks Burbank's keen eyes might single out one or two that looked promising, and these were kept and cultivated until they in their turn bloomed and seeded. In the end it might be that no more than a single plant was saved out of hundreds, and that this one was merely promising. Then it would be crossed with some other plant, and their progeny in turn tried out. The Shasta daisy, of which we have spoken, was obtained by crossing a common American daisy with an English daisy and crossing the hybrid thus obtained with quite another daisy from Japan.

Burbank's patience was as amazing as his genius. Months and years of toil often resulted in nothing, yet he was never discouraged. Take, for instance, his experiments with the native Californian dewberry. He treated the blossoms of this plant with pollen from the apple, quince, pear, cherry, hawthorn, strawberry, and other fruits, and eventually secured five thousand seedlings. As he said himself, stranger plants were never seen. Some had strawberry, some raspberry leaves, some prickles, some none. But of the whole five thousand only two bore fruit. These fruits looked promising, but imagine the disappointment of the inventor to find that neither had seeds. All were destroyed. No wonder he said with his whimsical smile, " Most of my plants are raised for the brush pile."

Luther Burbank worked for the sheer joy of working, and even when seventy years old still spent fourteen hours a day in his garden. You cannot take out a patent for a new plant as you can for a new sort of tin-opener or shoehorn, and though the plant wizard made large sums of money by selling his novelties, all that money went back into his experiments. He confesses to having put two hundred and fifty thousand dollars (£50,000) of his own earnings back into the work.

In his earlier days he suffered from neglect and poverty; later, when he became famous, he suffered almost equally from popularity. From 1904 onward his grounds were overrun with visitors, the number averaging six thousand yearly. His grounds were overrun with people from dawn till dark. Some of his most precious plants died for lack of care, and even on Sundays and holidays he was allowed no rest. Even his sleep was disturbed. Letters piled up beyond the possibility of answering, and even telegrams remained unopened. For days together he was forced to take his meals standing. This went on until his health gave way and he was forced to put a notice on his gates, " Positively no visitors allowed," and to hire an assistant who stood in a little office built just outside the gate and whose sole duty was to deal with visitors and take orders for seeds, bulbs, or trees.

It is pleasant to know that Luther Burbank lived to enjoy world-wide fame and success. When he died in 1926 at the age of seventy-seven his name was known throughout the civilized world and his plants had taken root in every country.

CHAPTER V

THE DISCOVERERS OF RADIUM

The Story of the Curies

THERE is no such thing as *pure* radium. The metal can be isolated, of course, but if that is done it almost immediately forms a compound again. Radium resembles sodium in having such a fierce affinity for oxygen that when isolated it is at once oxidized by the air. What is generally referred to as radium is actually chloride of radium. It resembles small crystals of common salt which may be crushed into a fine powder, but it is so powerful and terribly destructive a substance that it has to be kept in a glass tube wrapped with lead foil. Lead is impervious to the rays emitted by radium, but glass alone is not.

The story of Becquerel's burn illustrates the tremendous potency of radium. Some little time after Mme Curie had succeeded in extracting small quantities of radium salts from the mineral pitchblende, M. Becquerel, the original discoverer of radio-activity, visited London. He carried in a waistcoat pocket a little glass tube containing a mere speck of the newly found substance, a speck little larger than the head of a pin. It was so precious that he kept the tube always about his person.

In about ten days' time he became aware of a sore spot on his side exactly where the radium tube pressed against it, and he found that this place was actually burned. The rays emitted had destroyed some of the cells of his flesh. Despite the best medical attention, the deep and painful sore thus caused took weeks to heal.

It has been found that a tube of radium suspended a few inches over the heads of a family of young mice rapidly kills them, and the effect upon the larvæ of grubs of meal-worms is still more astonishing. These radiumized grubs never turn into beetles, but remain worms for the rest of their existence.

Doctors soon realized that rays which had so powerful a destructive action might have great value as a curative agent. The first use to which radium was put was the cure of warts. The common wart, though most people think little of it, can become a very serious trouble. It may occur, for instance, on the sole of the foot and make the sufferer quite lame, or on the eyelid, with danger to the sight. Warts have been known to appear on the tongue, and even under a fingernail.

A surgeon, of course, can cut out a wart, but it is very apt to return. Dr Abbé began to experiment with two and a half grains of radium supplied by Mme Curie, and soon found that one thirty-minute application of radium would cure any wart. What is more, there is no scar left as is the case when the surgeon's knife has been used. Dr Abbé had as a patient a girl with a beautiful voice. A wart developed on her vocal cords. It was cut out, but came again, and a second time the same thing happened. The poor girl began to lose her voice, and, worse still, the growth increased in size until it threatened to choke her. Radium was used—simply held over the wart for about half an hour. Within a very short time the wart began to disappear. The girl was able to breathe comfortably, her voice came back, and before long she was as well as she had ever been in her life. When doctors realized what radium could do in removing warts they began to try its effects on more dangerous growths, and to-day radium is the chief weapon with which doctors fight that most terrible disease, cancer.

Since those early days many discoveries have been made. Radium is now known to emit three different kinds of rays, which are called *alpha-*, *beta-*, and *gamma*-rays. In the chapter on Sir Ernest Rutherford's work we shall tell of the use he has made of *alpha*-rays for breaking up atoms. They were *alpha*-rays that burned M. Becquerel. *Beta*-rays have quite a different action. They increase growth, and it has been found that plants can be stimulated by these *beta*-rays into a most amazing luxuriance.

Of one hundred rays given out by radium ninety are *alpha*-rays, nine are *beta*-rays, while only one is a *gamma*-ray, yet these *gamma*-rays are the most wonderful of the three. It has been discovered that they travel with the velocity of light—that is, in round numbers, at a speed of one hundred and eighty-five thousand miles a second—and that they have a tremendous power of penetration. A sheet of paper will cut off the *alpha*-rays, a sheet of tinfoil will stop the *beta*, but the *gamma* will penetrate half an inch of solid steel, and it is these *gamma*-rays that have such a marvellous effect upon what are called malignant growths.

Perhaps the most astonishing thing is that they have what is termed a selective quality. They pass through healthy tissue, leaving it unharmed, and only attack the diseased tissue. We do not know the cause of cancer, whether it is a germ or a parasite or a poison, but whatever it is the *gamma*-rays of radium will attack it, break it down, and in many cases effect a complete cure. Very large doses of *gamma*-rays can be used without harming the patient, but the difficulty is that there is not nearly enough radium chloride in existence for the purpose for which it is so sadly needed.

And this brings us back to what is really the subject of our chapter, the beginnings of radium. Pierre Curie, the son of a Parisian doctor, was born in the year 1859. His father was a remarkable man. Instead of bringing up his sons on the usual conventional lines he encouraged them

THE LATE PROFESSOR CURIE

to think for themselves, he taught them to love nature, and to try to get their knowledge first-hand. Pierre and his brother Jacques were very happy boys and very good chums.

Jacques was a man of action, but Pierre was a thinker and a mathematician. We may say here that you cannot be a sound scientist unless you are fairly good at mathematics. In his spare time Pierre liked wandering in the country, and sometimes he would spend half the night alone in the woods, savouring the sweet smells and revelling in the beauties around him.

When he was only nineteen Pierre got his degree in physics, and became an assistant in the Sorbonne. He was interested in electricity; he and Jacques together did some good work in this direction. Four years later we find that Pierre Curie had risen to be chief of the laboratory at the new School of Industrial Physics in Paris, and that he had earned a reputation as a first-class teacher who was extremely popular with his pupils. So he carried on for thirteen years, enjoying a very friendly, happy, and busy life. Then came a great change, for he fell in love with one of his pupils.

This lady was of Polish birth, and her maiden name was Marie Sklodowska. She was born in Warsaw in 1867. Her father was a teacher of Science, but the laboratory in which he worked was very poorly equipped. The college authorities in those days thought little of Science, and Marie's father had actually to pay for a good deal of the apparatus out of his own pocket. This left him so badly off that he could not afford an assistant, and he was grateful to his little girl when she insisted on coming in and washing test-tubes and tidying up for him. The child grew up in the laboratory, and soon began to take the keenest interest in her father's work. Even when she went to school during the day she always came to the laboratory in the evenings to help.

At that time Warsaw was sorely oppressed by her Russian masters, and there began one of the movements for Polish independence. Marie herself was one of the rebels, but the movement failed, and Marie was driven from her home, and fled to Paris. She was only twenty-two, she had no friends, no money, and only her brains and industry to save her from starvation. She rented a garret in a poor quarter, lived on bread and milk, and made her slender living by giving lessons.

After a while she obtained work at the Sorbonne. It was mainly a matter of washing bottles and preparing furnaces for chemical experiments, but she did the work so well and gave evidence of so much knowledge that presently she attracted the notice of the head of her department, whose name was Gabriel Lippman, and of the great Henri Poincaré, who is mentioned in another chapter of this book as one of Einstein's first converts. These two found out who she was, wrote to her father about her, and presently, to her great joy, Marie became a student under the gentle and clever Pierre Curie.

Marie was a handsome girl with beautiful fair hair and eyes between blue and grey. She had and has a very gentle yet firm manner and a charming voice. Pierre Curie was tall and stooping, with a brilliant smile. Both were poor, yet both were devoted to their work. As we have said, they fell in love, and in 1895, when Pierre was thirty-six and Marie twenty-eight, they were married. They could not afford a servant. Pierre swept the floor, Marie cooked the simple meals, but they were extremely happy. They did not go out much, and often they spent the evening quietly together, talking over some problem of Science.

In 1895, the year they were married, the whole world was stirred by Röntgen's discovery of X-rays capable of penetrating flesh and many other substances, and of affecting a photographic film even through black paper.

A year later Becquerel, who was a colleague and friend of the Curies, discovered other radiations (from compounds of the very heavy metal uranium), and these, like X-rays, could penetrate opaque substances.

The Curies were intensely interested, and Mme Curie began the work of testing all known elements to see whether any others, apart from uranium, showed signs of emitting these extraordinary rays. She used a little instrument called the electroscope, which is fitted with leaves of fine gold-foil. These are electrified, and any radio-active substance causes these leaves to collapse. But the leaves do not collapse at once, and the rate at which they do so can be used to measure the radio-activity of the substance being tested. In testing a sample of pitchblende, which is the mineral from which uranium is extracted, Mme Curie was astonished to notice that the amount of radio-activity shown was *four times as much as could be expected.*

The Curies agreed that this indicated the presence of some hitherto undiscovered element which was enormously more powerful than uranium. They decided to collaborate in trying to find this new element.

The next question was how to get enough pitchblende for their purpose. Certainly they had not money to buy it. Then the Austrian Government kindly sent them a whole ton of pitchblende from its own mines in Bohemia. It was a handsome present, for this ore is worth more than two thousand pounds a ton. Then began the colossal task of trying to reduce this mass of intensely hard rock and of searching through it for the unknown element.

The method employed was what is called fractional crystallization, and the work had to be done over and over again, first in a foundry, then in an old wooden building used as a laboratory. Weeks passed, and still the pair worked unceasingly, testing and testing as they went on. The ore had to be boiled, filtered, decanted, and crystallized, over and over again. At last a strongly radio-active substance was obtained. Mme Curie called it polonium, after her own native land. But this was not the end of the search, for it was clear that there was something even more powerful connected with the barium residue of the mass they had treated.

Mme Curie kept on steadily, and at last in 1902 succeeded in isolating a salt of radium. The amount obtained was just about enough to fill a small salt-spoon. The work had taken four years, and had been not only difficult, but also dangerous, for Pierre Curie's hands were in a sad state as the result of handling tubes of radium. At that date no one had yet realized the danger of the rays emitted at such enormous speed.

In 1903, before the Paris Faculty of Science, Mme Curie read a paper on her researches, and woke up next day to find herself famous. She received her doctor's degree, and was besieged by reporters and photographers. The latter she dodged as best she could, for Mme Curie is modest.

A few months later the Curies visited London at the invitation of Lord Kelvin; the Davy Gold Medal of the Royal Society, one of the greatest honours Science can bestow, was awarded them. Later in the same year another reward came their way; this was the Nobel Prize, a sum of nearly six thousand pounds, a fortune to two people of tastes as simple as theirs.

While in London, M. Curie lectured on radium before the Royal Institution. His hands were so sore and blistered that he was unable to dress himself, yet he managed to handle his apparatus, and his lecture created a tremendous sensation. To prove that radium throws off heat continually he took two glass vessels, one containing a thermometer and a tube of radium, the other a thermometer but no radium. The thermometer in the former

MADAME CURIE

Madame Curie continued her late husband's work for the good of humanity.

Photo by Henri Manuel and L.E.A.

vessel was seen to register constantly 5·4 degrees Fahrenheit higher than the latter.

He also showed how the yellow powder of zinc sulphide bursts into a brilliant glow under the stimulus of radium emanation. It was through this experiment that Sir William Crooks devised his spinthariscope, which allows one actually to see radium breaking up and flinging off a never-ceasing shower of atoms in a myriad of tiny blazing stars.

M. Curie also proved that all substances may be rendered radio-active by being exposed to the emanation of radium. Lead, rubber, wax, celluloid—fifty substances in all—were so tested. Another very interesting point he made was that radium provides an easy means of distinguishing real diamonds from imitations, since it causes the real stones to glow with a brilliant phosphorescence, while the sham stones remain unaffected.

A result of these new discoveries was that in 1904 a new position was created specially for M. Curie at the Sorbonne, and his clever wife was appointed "chief of staff" under him. The post carried a fair salary, and for the first time in their lives these two hard-working geniuses found themselves comfortably off. They already had one daughter, and now a second was born, and for a time their life was both busy and happy.

Then came disaster. On a day in 1906 Pierre Curie went out to lunch with a few intimate friends. He was very gay and happy, for, as he told them at lunch, he was now going to give up teaching and to devote all his time to research. He left his friends and started homeward on foot. As he crossed the crowded street he was knocked down by a carelessly driven dray and killed on the spot.

Poor Mme Curie suffered terribly, but she was too strong a character to succumb altogether, and after a time she went back to the laboratory and to work. She told her friends that while life remained to her she would carry on with the researches which she and Pierre had begun together. Very wonderfully she carried out her promises, and in 1910 she isolated radium—that is, she obtained it in its pure state—and determined its atomic weight. She published her wonderful treatise on radioactivity, and in 1911, for the second time, she was awarded the Nobel Prize, and made a member of the Swedish Royal Academy. The French Institute, simply because it had never yet admitted a woman, refused to make her a member, but the French Government placed her at the head of its new Radium Institution, and in 1914, when the Great War broke out, appointed her as the head of all radiology in the military hospitals.

When radium was first discovered by the Curies the world at large jumped to the conclusion that this substance was going to work miracles for mankind. It was not only to cure all sorts of skin diseases, but to afford a new source of power. If these expectations have not yet been realized it is largely because the supply of the element is so small and its cost so enormous. It is true that radium exists almost everywhere in all hard rocks, also in sea-water, but the amounts are very small. Even in good pitchblende radium exists only to the extent of one part in two million. Thirty tons of pitchblende yield only one-tenth of an ounce of radium, and the work of extracting it from this ore is very long and very costly.

Some curious calculations have been made relative to the amount of radium in sea-water. A cubic mile of sea-water contains a little over a tenth of an ounce. A box each side of which measured 1·97 miles filled with water from the Atlantic Ocean would give just one ounce of radium. In all the years that have elapsed since the first discovery of the metal no means have been discovered of greatly increasing the supply of it, and hospital authorities all over the world are complaining that they have not nearly enough for use in fighting the dread disease of cancer. In Britain a Radium Commission has been formed to deal with the problem. This has its offices in Adelphi Terrace, London. So enormous is the cost of radium that a pound of it (if any such amount were obtainable) would be worth more than five million sterling. It is indeed the most costly thing in the world and far above the price of diamonds or rubies.

Yet it is possible that in the depths of the earth there may exist great stores of this immensely precious and powerful substance. Years ago Sir Ernest Rutherford suggested that the heat of the earth may be due not to the fact that it is a molten mass which has been slowly cooling for millions of years, but to the presence, in its heart, of large quantities of radium. For the heat given off by radium is very great; it is estimated that thirty-two tons of radium used in the furnaces of the *Mauretania* would propel that great ship at the same speed as the hundreds of tons of oil fuel used daily during her voyages —and that it would do so indefinitely.

Yet even supposing that we were to find some method of procuring radium cheaply and easily, it is doubtful whether we could use it industrially, for the danger of handling it would be terrible. A single pound of radium placed in an ordinary room would probably blind and kill any living creature that came near it.

CHAPTER VI

UNLOCKING THE SECRETS OF THE FROZEN SOUTH

Sir Edgeworth David's Discoveries in the Antarctic

THE search for truth makes men embark on strange quests. While one scientist works in his laboratory, seeking to split the atom, another may be risking his life journeying to the ends of the earth in order to measure a mountain, or seeking some scrap of knowledge which will help us to understand why there are wet and dry seasons. To some, scientific research means gazing through powerful microscopes month after month, hunting with infinite patience for the secret which eludes them. To others, their scientific work means leaving civilization for long periods, and pitting their strength against the forces of wild nature, in the company of intrepid explorers, whose work would be incomplete were not the scientist there to interpret the secrets of the hitherto untrodden regions to which they penetrate.

Of all the explorer-scientists of our generation, one of the greatest is undoubtedly Sir Edgeworth David, the discoverer of the South Magnetic Pole, and the leader of the first party to climb Mount Erebus, the highest peak in the Antarctic. It was Sir Edgeworth David also who collected and brought back much valuable information about coal in the Antarctic, and about the effects of climatic conditions there upon the weather experienced in other regions of the earth. His too is the credit for some remarkable calculations concerning the past of the South Polar region and its future possibilities; these, by the way, reveal nightmare possibilities for the rest of the world.

SIR EDGEWORTH DAVID

Such a record, achieved in the face of terrible weather in a part of the world about which very little is known even to-day, is one of which any man might well be proud. To be the first man to reach the South Magnetic Pole—the point to which all compasses turn in the whole Southern Hemisphere—Edgeworth David had to haul a loaded sledge for 1260 miles across the great snow desert. But his discoveries seem even more remarkable when we consider that he was fifty years of age at the time when he went south with Shackleton! Yet he carried out his work on the Ice Barrier, under the most trying conditions, without a day's sickness. How many other men, one wonders, could thus leave a kindly climate and the comparative ease of a laboratory and turn themselves into explorers, braving the worst climate in the world, at an age when many are thinking of ease and comfort?

Sir Edgeworth David is a Welshman who has for thirty-nine years occupied the Chair of Geology at Sydney University, New South Wales. He is an acknowledged world-authority on dynamical geology, glaciation, and other branches of Science which sound fearsome, though really they are enthralling, for they deal with the earth and its minerals, climate, and the changes which have occurred in the earth's long history.

It was in 1908 that Professor Edgeworth David accepted an invitation from Sir Ernest Shackleton, who was forming a new expedition to the Antarctic, to accompany his ship, the *Nimrod,* as far as winter quarters at the Great Ice Barrier, so that he might there 'on the spot' give the expedition the benefit of his advice before returning to Australia, after shore-parties and supplies had been unloaded. With him were two brilliant young scientists, Douglas Mawson, now famous in the annals of exploration, but then a young man of twenty-eight years of age, beginning his distinguished career as an explorer, and Leo Cotton, aged thirty. Cotton was to return with Professor David, while Mawson remained at winter quarters to assist with the scientific objects of the expedition during the absence of the ship.

The voyage began on New Year's Day 1908, a day of blue skies and summer heat. Tugs crowded with well-wishers kept the *Nimrod* company as she crept out of Christchurch, New Zealand, and turned her nose to the south.

It was a happy send-off, but within a few hours of sailing the ship was wallowing in heavy seas, and had developed a corkscrew roll which proved too much for the scientists on board. Nearly all were violently seasick, and unable to leave their bunks.

Conditions were cheerless enough. The sleeping quarters were in a part of the hold which a few months before had been filled with blubber and seal-skins caught off Newfoundland. The aroma of fishy fat still permeated the atmosphere. There was no ventilation and only one small lantern. As the storm outside increased the seas swept the decks and found the weak points, soon penetrating to the sufferers below. If they left their soaking bunks, there was nowhere else to go. The ward-room was awash, the decks unsafe, the tiny vessel loaded to the last inch with stores and equipment. As one who was on board told the authors, a geologist was seen washing about in the scuppers, quite indifferent as to whether the next wave carried him overboard or not.

These were only the mild beginnings of the discomforts endured by these men, unused to sea-life, for the bad weather lasted ten days. The tremendous seas carried away the forward bulwarks at both sides, and even a part of the bridge rails. The pumps were at work continually, but despite strenuous efforts, in which the scientists joined, the water at one time rose so high that it flooded the stokehold and threatened to put out the boiler fires.

Life became a matter of changing wet clothes for others less wet. It was cold and raw, with frequent rainstorms, and the light clothing which the scientists had worn when leaving the tropical heat of New Zealand at midsummer had to serve until it went to pieces on their bodies. Worst trial of all was the lack of sleep. For ten days these scientists, straight from the luxuries of civilized life, endured sea-sickness, cold, wet, and sleepless fatigue in a small ship of two hundred tons which often rolled at an angle of fifty degrees. And they did it, not for adventure, as the others on board, but because they wanted to solve some of the secrets which awaited them in the Great White South beyond the storms.

None stood the battering better than Edgeworth David, despite his fifty years, and when on January 15th the first ice was sighted, and the sun came out, he was still fit and encouraging the others. As one of his companions on that voyage told the authors: "Despite the gruelling, the Professor was an incurable optimist. His superhuman energy put fresh heart into some of the younger men. I have seen him at the pumps for hours on end, wet through. And when his spell came to an end, he would sit down in his soaking clothing and write out the meteorological report as carefully and precisely as though he were in his study in Australia."

Thirty-eight days after entering the ice the *Nimrod* reached the spot chosen by Shackleton for his winter quarters, and the shore-party was landed at Cape Royds. According to plan Professor David should have returned to New Zealand with the ship, but the fascination of the Southland was too much for him, and there was jubilation among the members of the expedition when Shackleton announced that Professor David had decided to remain and assist with the scientific work before them.

The Professor had not been long ashore before he decided upon his first task. He would measure a mountain, one which had never been accurately surveyed. He proposed to Shackleton that he should attempt to reach the summit of Mount Erebus, the highest peak in the Antarctic, which had never been climbed, and there take observations of temperature and wind currents.

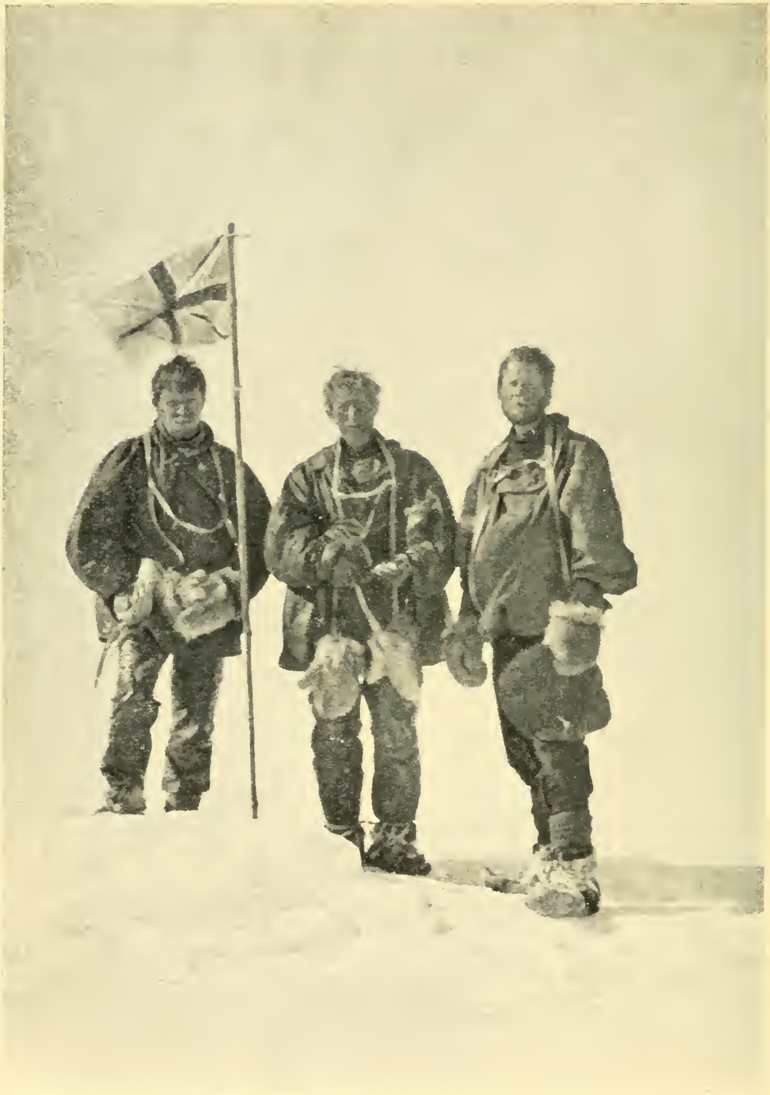
Mount Erebus has loomed large in the history of Polar exploration. Standing as the sentinel at the gate of the Great Ice Barrier, it forms a magnificent picture, rising from sea-level to a height of over 13,000 feet. It is an extinct volcano, and at the top an immense depression marks the site of the old crater, while beside this is an active cone often wreathed in smoke or steam. The ascent of such a mountain would have been difficult in any part of the world; in the Antarctic temperature and weather combined to make it a formidable task.

A climbing party was selected, consisting of the three scientists, Professor David, Mawson, and Mackay, with a supporting party of three other members of the expedition. They carried ten days' provisions. All recognized the scientific value of the attempt and all were determined to reach the crater.

During the ascent the parties encountered terrible blizzards, with temperatures as low as thirty degrees below zero. In five days they reached the summit, and there the Professor made some interesting observations, and for the first time the height of the mountain was scientifically calculated. This had been variously estimated. Sir James Clarke Ross, who named the mountain in 1841, estimated its height to be 12,367 feet. Captain Scott, on his first expedition in 1901, made two estimates, one being 13,120 feet and the other being 12,922 feet. The latter figure appeared in the Admiralty chart of the region.

Professor David's observations revealed that the rim of the main crater of Erebus was 11,350 feet above sea-level, and that the height of the summit was 13,355 feet.

The party had to face severe conditions on the return



PROFESSOR EDGEWORTH DAVID PHOTOGRAPHED IMMEDIATELY AFTER HOISTING THE UNION JACK AT THE SOUTH MAGNETIC POLE

Professor David is in the centre. With him are Dr (now Sir) Douglas Mawson and Dr Forbes Mackay.

Reproduced from "The Heart of the Antarctic," by Sir Ernest Shackleton, by permission of Lady Shackleton journey, but they reached winter quarters safely—the only casualty being one case of frostbite.

The coming of the long Antarctic winter prevented further expeditions for some months, during which the usual routine was carried out, while the scientists worked in their various spheres compiling records.

But they were anxious to begin the real work that awaited them—and none more so than the scientist who was the veteran of the party, and who had remained in excellent health throughout the dark months. Before the sun returned Shackleton, Professor David, and a third member of the company set out on a preliminary sledge journey, taking with them a fortnight's provisions. While out they had to face extreme temperatures, even for the South. At one time the thermometer registered sixty-one degrees below zero, or ninety-three degrees of frost. At this extreme of cold the greatest care must be taken not to expose any part of the body to the air, or frostbite will result. All returned safely after a journey which gave Professor David a vivid idea of sledging on the Ice Barrier and prepared him for a bigger task which he had decided to attempt—the discovery of the South Magnetic Pole.

The Magnetic Poles are not fixed points, but a knowledge of the exact position of this point of magnetic attraction, revised from time to time, is necessary to enable sea captains, whose compasses are controlled by its influence within the Southern Hemisphere, to discover their position with greater precision than would otherwise be possible. Our earliest knowledge of the point of attraction within the Southern Hemisphere depended upon observations made in 1841 by Sir James Clarke Ross, the famous Antarctic explorer after whom the Ross Sea is named. Between that date and 1902, when Captain Scott made renewed observations at a distance while on his first expedition, the South Magnetic Pole had moved two hundred miles eastward. Professor David wished actually to reach the Magnetic Polar point itself, and so to check these observations further, thus for the first time providing mariners with exact information concerning the point to which their compasses swung south of the equator.

There was also another reason in Professor David's mind when he started out on the long trek on October 5th, 1908, accompanied by Dr Mawson and Dr Forbes Mackay. He wanted to take possession of the South Magnetic Pole in the name of Britain, and hoist the Union Jack there.

It was a formidable task, for all three men had to drag behind their backs over two hundred and forty pounds. And remember that the Professor was fifty years of age! No wonder that several members of the expedition felt that he was taking an undue risk—that he should have been content to advise the others, and remain at the base.

For days and weeks they sledged steadily on—up the glaciers and on to the plateau, 7000 feet above sea-level. Several times they narrowly escaped being hurled to death down crevasses which opened in the ice at their feet. But good fortune was with them, and on January 15th, one hundred and two days out, observations taken by Mawson showed that they were nearing their objective.

The observations made with their compasses that day showed the angle to be only fifteen minutes off the vertical, the dip being 89° 45′, whereas at the Magnetic Pole itself the dip is 90°. The same evening it was 89° 48′.

It should be explained that the compass familiar to everybody is mounted on a vertical pivot and can therefore swing in a horizontal direction only. These compasses are controlled by magnetic force coming from the earth at the point of attraction, and if they were taken to the Magnetic Poles, where the magnetic force is vertical, they would be unaffected and useless.

For this reason the compasses used in the Antarctic are of the dip circle variety, consisting of a magnetized needle swinging on a horizontal axis, and the readings are taken in degrees from the vertical, which in turn show the approximate position of the compass in relation to the Magnetic Pole by which it is affected.

Though scientists have discovered how to measure the position of any part of the Southern Hemisphere in relation to the centre of magnetic attraction, very little is known about the Magnetic Poles or the forces which govern them. To quote one authority:

> The Magnetic Poles are not fixed spots, but are constantly travelling onwards, executing an unknown path and apparently completing a circle in a period of many hundreds of years. In addition to this onward movement of a few miles a year, there is a lesser daily oscillation.

That is the yet unsolved mystery of the mighty force which controls the pocket compass treasured by nearly every boy. And it was a desire to investigate one aspect of that mystery—the exact position of the South Magnetic Pole in the year 1909—that took Professor David and his companions on their long march.

A dip of 89° 48′ on the compass told the party that they were nearing the Magnetic Pole itself. The next morning they were away early, determined to reach the exact site of the Pole that day. And at 3.30 P.M. on January 16th, 1909, in latitude 72° 25′ south and longitude 155° 16′ east, Professor David and his companions bared their heads and hoisted the Union Jack, while the Professor uttered these words: " I hereby take possession of this area containing the Magnetic Pole for the British Empire."

Thus was fulfilled the wish of Sir James Clarke Ross, who had reached the North Magnetic Pole in 1831 and ten years later made the first observations concerning the exact position of the Magnetic Pole in the Southern

Hemisphere, and who hoped that a British subject might complete the work which he began.

The return journey was begun, and after hard travelling for fifteen hours a day the scientists reached the point at which it had been arranged for the ship to pick them up. They were days beyond their time, which worried both them and the party aboard, for if they missed the ship they would be compelled at tremendous risk to sledge over the sea-ice to Cape Royds.

They arrived in time, and were taken on board after covering a distance of over 1260 miles without any assistance from dog-teams or supporting parties. And, we may add, the Professor was as fit at the end of the hard journey across the great snow desert as he had been when setting out—a remarkable achievement.

This account of the journeys made by Sir Edgeworth David during that expedition by no means completes the scientific work which he accomplished while in the South. Some of his other discoveries were referred to by the Professor himself in a lecture which he afterward delivered at the Royal Institution in London.

He referred then to the existence of a vast coalfield, probably at least 1000 miles in length and from fifty to eighty miles in width—perhaps the largest unworked coalfield in the world—which was discovered in what is known as the Australian sector of the Antarctic. The expedition of which he was a member discovered seven seams of coal at the head of the Beardmore Glacier, of which at least one seam was of workable quality.

Later discoveries, the Professor pointed out, prove that when the numerous coalfields in this region were formed there was probably little if any ice at the South Pole, the whole continent being covered with a growth of dwarf trees, probably of conifers and low shrubs. The evidence on the American side of Antarctica indicates that at three or more subsequent epochs what is now a land of eternal ice and snow was clothed with abundant vegetation.

Equally interesting were Professor David's investigations concerning the depth of the Antarctic ice-cap and his speculations as to the fate of the world if the South Pole became warmer. Whereas most continents are surrounded by a submerged platform one hundred fathoms below sea-level, Antarctica has a platform two hundred fathoms deep. This the Professor attributes to the weight of the 5,000,000 square miles of Antarctic ice-cap, which has depressed Antarctica the additional six hundred feet below normal depth.

He suggested that because of this the thickness of the ice-cap could be measured, for the basic rock material of the continent is three times as heavy as ice—therefore to depress the whole of Antarctica 600 feet three superimposed layers of ice each of that thickness would be necessary. Thus the average thickness of the Antarctic ice-cap is approximately 1800 feet.

The thickness of this ice-cap and the problem of whether it will increase or thin out in the future are matters of enormous importance to the world. The ice-cap extends for 5,000,000 square miles, and represents more than one-thirtieth of the whole area of the oceans of the world. It can be stated, therefore, that for every thirty feet in thickness of ice melted off the Antarctic continent by any change in climate, the sea-level of the whole world would be raised one foot, thus submerging all wharves, docks, and warehouses and all tracts of country below that level.

Geological evidence shows that this danger cannot entirely be dismissed. In most parts of Antarctica the volume of ice is lessening rapidly, and the ice was formerly at least eight hundred feet thicker than it is at present. At that time the sea-level all over the world must have been some twenty-five feet lower than it is to-day. Not the least interesting piece of scientific work which still awaits future explorers will be the completion of the evidence on which these figures can be examined by a search for information concerning the past and present thicknesses of the ice-cap, and the determination of the areas over which it is waning, together with its rate of movement seaward, and the source of the snows that feed it.

The more immediate task awaiting the scientist in the Antarctic, however, is the further study of meteorological conditions there. The South Polar region is the greatest refrigerator of our planet, and though its effects are passive compared with the sun's heat—the latter being the main controller of both weather and climate on the earth—Antarctic weather conditions have a very distinct effect upon climate in general. Sir Edgeworth David is of those who believe that long-range weather forecasts may be made possible by the results of further scientific investigations in the Great White South.

CHAPTER VII

THE STORY OF GREENWICH OBSERVATORY

Sir Frank Dyson, Astronomer Royal

A BOY, asked what he knew about astronomers, said, " They discover new stars and generally live a long time." The second part of his answer may have been right, but the first was hardly correct. That is the popular idea of the astronomer—that he spends hours on clear nights at the eye-piece of a mighty telescope, searching the starry sky.

Actually the professional astronomer is seldom thus employed. He has little time or opportunity for searching the night sky or making discoveries. His work is something between that of an engineer and an accountant. He makes observations—thousands of them—and records them with the most extreme care.

Our own Royal Observatory, standing on top of a small steep hill in Greenwich Park, was built simply to help sailors in their navigation when out of sight of land, and that in a wide sense remains its object and constitutes the work of the Astronomer Royal, Sir Frank Dyson, and his corps of hard-working assistants.

To-day you go down to Southampton and board a steamer for New York with the knowledge that the ship will carry you there along a certain line ruled across the Western Ocean almost as definitely as a railway track. You take it as a matter of course that every ship on the sea shall find her way direct to her destination, probably without giving a thought to those who have made this possible.

Yet less than two hundred years ago the great problem before every ship's captain out of sight of land was to know where he was. Latitude—that was easy enough, for it could be found by observation of the sun at midday or of the Pole Star at night; but longitude was a very different matter. You will remember that Christopher Columbus started across the Atlantic, not in the hope of discovering America, of which he knew nothing, but with the idea of finding a new route to India, for one thing he did know was that the earth was round. After many days he sighted the Bahama Islands, which are actually in sixty-six degrees west longitude, but he was so hopelessly out in his calculations that he believed he was among islands in the China Seas, two hundred and thirty degrees west from Spain.

And such blunders were made for a very long time after Columbus. In the eighteenth century Commodore Anson wanted to make the island of Juan Fernandez in order to get fresh water and fruit for his crew, who were dying of that terrible disease scurvy. He got into its latitude easily enough, and sailed eastward, though as a matter of fact he was *already* east of the island. In consequence the first land he sighted was the mainland of South America, and he had to turn round and sail westward for days, losing many poor fellows whose lives might otherwise have been saved.

To go back to the time of Columbus, the discovery of America caused such a rush of adventurous voyagers in that direction that the need for some means of finding their longitude became most pressing. Clever men all over the world tackled the problem, and in 1598 Philip III of Spain offered the huge prize of one hundred thousand crowns to anyone who could solve it, while the Dutch followed with an offer of thirty thousand florins.

The only man who came anywhere near a solution was the great Galileo. With his telescope he observed how the moons of Jupiter pass behind the planet, and he suggested that if ship-masters would observe these occultations they could make certain of the exact time and therefore of their longitude. In practice this method failed to work because the rolling deck of a small ship makes a very poor observation platform, and also because the disappearance of one of these moons does not happen instantaneously, but takes some time.

Longitude may be expressed as the difference between the local time of the place where the observation takes place and the local time of the place chosen as the standard meridian, or longitude nought, which is Greenwich. That, you may say, is simple enough. Why not carry a good watch? Quite so, but please remember that there were no time-keepers in those days except pendulum clocks, and these, of course, could not be trusted on board ship. There were no chronometers.

About the middle of the seventeenth century a new idea was mooted. The moon moves regularly and quickly among the stars, and it was suggested that if a table were drawn up of its distance from a number of fixed stars at definite periods for a long time in advance, this would be a good guide for the navigator.

This plan came to the ears of Charles II, who was extremely interested in scientific matters, and he at once desired some of the leading scientific men of the time to examine it and see if it were practicable. The Reverend John Flamsteed was selected to inquire into it, and presently reported that the scheme was a good one, but that at present there was no table of the fixed stars sufficiently reliable for the purpose. Whereupon the King appointed Flamsteed his Astronomer Royal and ordered the building of Greenwich Observatory.

Now we must say a little about Flamsteed. He was a Derbyshire boy, born in 1646, and was educated at the free school in Derby. He was always weak and sickly, so that even " one day's short reading caused him a desperate headache," yet that penalty never discouraged him, and he read everything that came his way. Also he learned mathematics from his father, who was an expert in this subject. An eclipse of the sun in 1662 interested the boy deeply and turned his thought to the study of the heavens, and in 1665 the appearance of a comet made him keener still. This delicate, sickly lad drew up a catalogue of seventy stars, calculating their ascensions, declinations, etc., for many years in advance; he attempted to determine the mean length of the tropical year and the distance of the earth from the sun.

In 1669 he sent some of his calculations to the Royal Society, and though he sent the paper unsigned the secretary found out who he was and wrote him a charming letter, signing it " your very affectionate friend and real servant." In 1670 his father sent him up to London, and he also visited Cambridge, where he met the great Isaac Newton himself.

This, then, was the young man who at the age of twenty-nine was appointed first Astronomer Royal at the munificent salary of one hundred pounds a year, and with no provision at all for instruments. As for his observatory, as at first built, it cost but five hundred and twenty pounds, yet its designer was Sir Christopher Wren. Its materials came from a gate-house of the Tower of London which had recently been pulled down, and the bricks from old Tilbury Fort. The actual money was obtained from the sale of spoiled gunpowder. It was just a small dwelling-house with an upper room to use as an observatory, but Flamsteed's royal patron failed to provide either instruments or an assistant.

The Royal Society lent Flamsteed a little money, and he was helped also by his friend, Sir Jonas Moore. Then he set to work and built instruments for himself. It must be understood that telescopes in the modern sense of the word did not then exist, and that Flamsteed's principal instrument was a mural quadrant of fifty inches radius. None of his instruments are now at the Observatory, but the dwelling-house of the Astronomer Royal still bears the name of Flamsteed House.

In 1684 Lord North gave Flamsteed the living of Burstow, in Surrey, and this added something to his miserably small income, yet even so he was forced to take private pupils in order to make ends meet. He had in all no fewer than one hundred and forty of these. It was bitter hard work for a man of Flamsteed's poor health and weak constitution, and how hard he worked may be gathered from the fact that in the thirteen years ending 1689 he made no fewer than twenty thousand observations, and revised the whole of the star-tables then in use.

Then his father died, and left him money enough to make life somewhat easier, and he was able to engage an assistant, Abraham Sharp, a brilliant mathematician and a most capable maker of instruments.

But fresh trouble was brewing. So far Flamsteed had not published his observations. He wished to finish them first and to correct them thoroughly. Sir Isaac Newton, however, began to press him to publish, and in the end there was a sharp quarrel between the two. The Royal Society turned upon Flamsteed, and Flamsteed complained with good reason that he was being robbed of the fruit of his labours.

In 1712 the work at last appeared in print. Four hundred copies were issued, but it was, says its author, full of errors, and he himself managed to get back three hundred copies, which he burned " as a sacrifice to heavenly truth."

Flamsteed died in 1719, and was succeeded by Edmund Halley, who was also from a Derbyshire family. Like Flamsteed, Halley had taken to astronomy as a boy, and when he was still quite a young man had travelled to the island of St Helena, where he spent a year and a half, observing the stars of the Southern Hemisphere. In 1678 he had become a member of the Royal Society, and, young as he still was, had had the honour to be chosen to lead a discussion, the subject of which was whether more accurate observations of the place of a star could be obtained by the use of sights or by the use of a telescope. This is good proof of the primitive state of telescopes in the seventeenth century.

It was Halley to whom we owe the publication of Sir Isaac Newton's *Principia*, certainly the greatest scientific work the world had yet seen, and it was Halley who took such interest in the behaviour of the magnetic compass that William III gave him a captain's commission in the Navy, and placed him in command of a small vessel called a 'pink,' so that he might study this subject. Study it he did, making long voyages far into the Southern Seas, as well as doing much work relative to the tides around British coasts. He was a good friend to Flamsteed, and at the latter's death was chosen to succeed him.

Halley was then over sixty years of age, and he came to an observatory where there were no instruments, for Flamsteed's widow had removed all her husband's property. Halley managed to get a grant from the Government, however, and made a transit instrument and a large quadrant, both of which still hang in the Observatory.

Halley's name is best remembered in connexion with Halley's comet. This great comet passed flaming through the solar system in the year 1682, and Halley, after computing its path, began to make investigations with the object of discovering whether this comet could have visited our system at any previous epoch. He found that it closely resembled in appearance and orbit a comet which had appeared in 1607 and another seen in 1531; he decided that this was the same comet, with an orbit of seventy-five to seventy-six years. He therefore predicted its return in 1758 or early in 1759. The prediction was a memorable one, because it was the first attempt to foretell the appearance of one of these mysterious bodies, whose visits seemed guided by no fixed law, they being always regarded as visions of awful import. On Christmas Day 1758 the comet was detected, and in the following March each night was lighted by its flaming splendour.

Halley remained at his post until his death, and was succeeded by James Bradley, already known through his efforts to fix the distance of the sun from the earth. In 1719 he was convinced that it could not be more than one hundred and twenty-five millions or less than ninety-four millions of miles. This lower limit has since been proved to be almost exact. But Bradley's greatest discovery was what is called the 'aberration of light.' In 1667 Roemer, a Danish astronomer, had discovered that light does not travel instantaneously from place to place. Aberration is an *apparent* alteration in the position of a fixed star, arising from the motion of the earth in its orbit, combined with the time taken for light to travel.

You can look at it in this way. When rain is falling straight down, a drop entering the top of a stationary tube goes right through and comes out at the bottom. But if the tube be carried forward, still in the same upright position, a drop entering the top will strike the side a little way down. Bradley's great discovery was that light from a star acts in similar fashion.

Bradley did an immense amount of valuable work at Greenwich. He observed the positions of more than three thousand stars, he determined the exact longitudes of Lisbon and New York, and his last work was the observation of the transit of Venus (the passage of the planet Venus across the disc of the sun) in 1761.

The next Astronomer Royal of note was Nevil Maskelyne, who was an ancestor of the well-known conjurer of that name. He was the first man to weigh the earth; this he did in 1774. When travelling in Scotland, he measured the deviation of a plumb-line from the vertical caused by the attraction of the mountain Schiehallion. Maskelyne did more work for navigation than any of his predecessors, and it was during his long tenure of office at Greenwich that the Government offered a reward of twenty thousand pounds for a clock or watch that would go perfectly at sea, notwithstanding the tossing of the ship and the great changes of temperature to which it might be subjected.

This prize was won by John Harrison, a Yorkshireman born in 1693, who as early as 1726 constructed a time-keeper 'compensated' against changes of climate. For years he toiled at his time-keepers, until at last he made a chronometer which in a voyage to Jamaica in 1761–62 determined the longitude within eighteen miles. But it was not until 1773 that Harrison, then an old man, received the full amount of the reward. His original chronometer is still preserved at the Observatory, and not long ago Commander Rupert Gould, R.N., succeeded in making it go again after many years of rest.

Maskelyne first published the long-desired *Nautical Almanac*, and superintended its publication until his death. He lived until 1811, and was succeeded by John Pond, who was famous for the accuracy of his observations. He ran the Observatory with an iron hand, which did not make his assistants either happy or useful.

His successor was George Airy, perhaps the greatest organizer who was ever in charge at Greenwich. Indeed, he entirely reorganized and almost rebuilt the Observatory; he installed new telescopes, and it was under him that photography began to play a part in astronomical observation. The eye of the camera never tires, and it is entirely by this means that the present marvellous star charts of the heavens have been compiled.

Airy was a strong man, perhaps somewhat selfish, but he placed the work of the Observatory before all personal considerations. We may quote words from his autobiography:

> The Observatory was expressly built for the aid of astronomy and navigation, for promoting methods of determining longitude at sea, and more especially for determination of the moon's motions. All these imply, as their first step, the formation of accurate catalogues of stars and the determination of the fundamental elements of the solar system. . . . It has been invariably my own intention to maintain the principles of the long-established system in perfect integrity, varying the instruments and the modes of employing them . . . as the progress of science might require.

It is to Airy more than any of those who preceded him that the great reputation of Greenwich Observatory is due. A famous foreign astronomer once said:

> Greenwich Observatory has, during the past century, been so far the largest contributor to the determination of geographical positions on sea or land that if this branch of astronomy were entirely lost it could be reconstructed from the Greenwich observations alone.

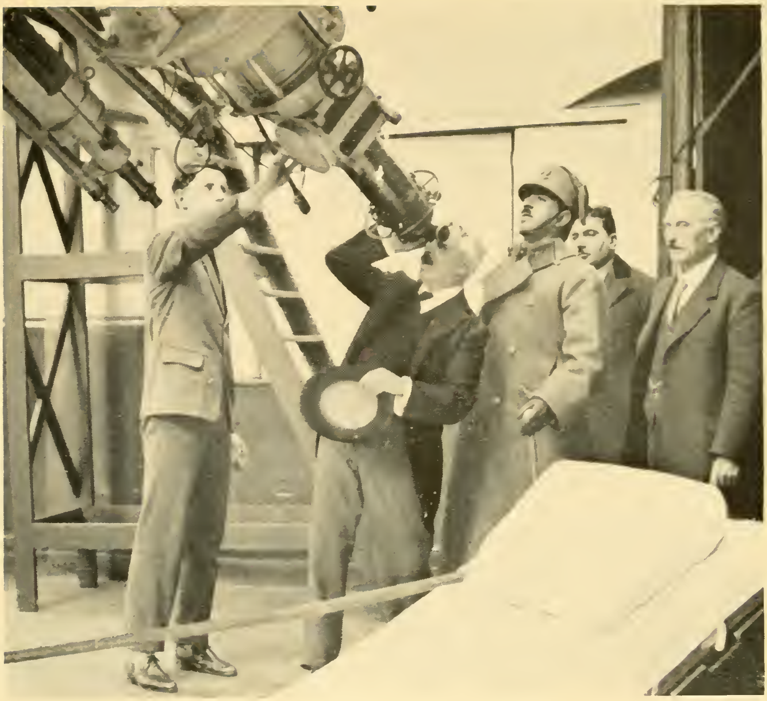
In 1836 Airy proposed the creation of the magnetic and meteorological department of the Observatory, with a system of regular two-hour observations. It was from this small beginning that we now have our marvellous, world-wide system of weather forecasting, which grows and improves with each successive year. Airy again it was who in 1873 formed the solar photographic department, to which was presently added the spectroscope, that simple yet marvellous instrument by which light is analysed and the composition of the heavenly bodies studied.

One of the many remarkable uses of spectrum analysis is that we are able thereby to measure the rate of approach or recession of a star. For instance, we know that Arcturus is hurrying away from the solar system at a rate of about twenty miles a second, while another star is approaching our system at the terrific speed of about fifty-five miles a second.

Airy was the first Astronomer Royal to busy himself with important work outside the Observatory. On three occasions he made long journeys to study eclipses of the sun; he went to America to help in settling the boundary between Canada and the United States; and he made an expedition to Harton Colliery, near South Shields, in order to study the decrease in gravity observable in the descent of a deep mine.

Airy lived to be over ninety. He was succeeded by W. H. M. Christie, who did a great deal in setting up new instruments, including two fine new telescopes. During his period the new library was built, as well as the Transit Pavilion and the Magnetic Pavilion out in the Park. The Observatory has indeed grown greatly since its foundation by Charles II. Flamsteed's little domain was only twenty-seven yards long by fifty deep, and consisted of little more than a dwelling-house with one fine room, the original 'observatory,' above it. To-day the enclosed ground measures about two hundred yards by sixty, and contains a large number of buildings and a garden.

We have all heard of 'Greenwich time,' which sets the standard not only for Britain, but for the world. One of the most interesting places in the Observatory is the room in which are kept the clocks. This room has double doors and is kept at a constant and rather warm temperature. The special clock is the Shortt clock made by the Synchronome Company. It is a two-clock combination, a free pendulum on one wall electrically connected with a slave clock on another wall. The mechanism is far too intricate for the writer to describe. It is enough to say



SIR FRANK DYSON, ASTRONOMER ROYAL, DEMONSTRATES ONE OF THE GREAT TELESCOPES AT GREENWICH OBSERVATORY TO EX-KING AMANULLAH

that the free pendulum acts in such a way that should the clock itself err even to the two-hundredth of a second it is instantly corrected by the pendulum of which it is the slave. This marvellous clock is of English make, and has been installed during the office of the present Astronomer Royal, Sir Frank Dyson.

A second clock in the same room automatically sends time signals to the great radio station at Rugby, whence they are wirelessed to all parts of the Empire. Navigators on all the seas receive these time signals by wireless, so that these clocks may justly be said to be the most important in the world.

The work done at Greenwich is still largely that of taking regular observations, such as observing the occultation or hiding of stars by the moon, the exact time and place of their disappearance and reappearance. You might suppose that this sort of thing was no longer necessary and that the moon's orbit was now perfectly known. But this is not so. If the earth and the moon were the only two bodies in the universe the problem would be simple. But the earth, the sun, and the moon are members of a triple system which is complicated by the faint pulls exercised by the planets, and the result is a problem of amazing intricacy. Calculations of the moon's movements need, therefore, to be compared with observations, and the task is endless.

One of the great triumphs of systematized observation was the discovery of the planet Neptune. The observed movements of Uranus were found to be out of accord with its computed movements, and simply from this fact Adams and Leverrier were able to state that there must be another planet outside the orbit of Uranus. It was in 1845 that Adams sent his calculations to Airy, showing that a new planet should be searched for, and in September 1846 Neptune was discovered by Dr Galle, of Berlin Observatory. Airy has been blamed for failing to search for the new planet from Greenwich, but at that time the best telescope at Greenwich was an equatorial of only six and three-quarter inches aperture, housed in a very small and inconvenient dome, an instrument quite unfitted for the work.

At present there is no lack of fine telescopes at Greenwich. The difficulty is that our climate is a very poor one for astronomical observation. According to our records, we have only one hundred and forty-one fine days out of the three hundred and sixty-five. That is why most of the great discoveries in modern astronomy have been made either in North America or South Africa. As Sir Frank Dyson said to the writer, the climate of the Pacific slope is almost ideal for observation of the heavens, while an observatory such as that of Mount Wilson has the additional advantage of being built sufficiently high (five thousand seven hundred feet) to be above mist, fog, and low-lying cloud.

Another advantage enjoyed by the American astronomers is the possession of telescopes of a size and power unknown elsewhere. These have been given by men of enormous wealth such as Carnegie and Yerkes. At Mount Wilson is the largest telescope in the world. It is a gigantic reflector one hundred inches across. The mirror is thirteen inches thick and weighs four and a half tons. The moving parts of this telescope weigh one hundred tons, and are driven by a powerful clock mechanism when following the sun or stars.

It must be remembered that the rapid movement of the earth has to be counteracted if a telescope is to remain focused on one particular part of the heavens.

The Mount Wilson telescope resembles a great naval gun, and is in a revolving dome of one hundred feet diameter. This telescope is about two and a half times more powerful than the sixty-inch which was previously the largest in existence, and has achieved important results. For instance, a star in Capella, hitherto shown as single even by the most powerful telescopes, was broken up and shown to be composed of two bodies revolving around one another in a period of one hundred and four days. The diameter of Betelgeuse has been measured and found to be two hundred and fifteen million miles. These figures will be better appreciated if we imagine Betelgeuse in our sun's place. Then this planet would be inside Betelgeuse and not half-way to its outer surface.

Not content with the one-hundred-inch reflector, the Californian Institute of Technology is at present endeavouring to construct one of two hundred inches. This will cost at least a million pounds, but if successful it should add several hundred million more stars to those already known; yet even so it is unlikely to solve the problem of whether Mars is inhabited.

The largest telescope at Greenwich is of only thirty inches aperture and is wholly devoted to the work of photographing stars. Much is being done nowadays in measuring the distances and temperatures of the stars. You might suppose it was impossible even to guess at the weight of a star lost in the depths of space, yet, as Sir Frank Dyson pointed out, if you know the distance of a pair of twin stars and their bulk, it is possible to calculate their weight with considerable accuracy. Again, the spectroscope enables astronomers to estimate the heat of stars. The spectroscope is used to collect and analyse the light collected by the telescope, and according to the proportion of light at the blue or red ends of the spectrum the heat of the star can be estimated. In brief, the greater the degree of blue the hotter the star.

In the Observatory are many photographs of the spectra of stars, but the pictures of greatest interest to the layman are those of solar eclipses, showing the immense prominences or flames which appear on the edge of the disc of the darkened sun. Of these the most interesting is that of the eclipse watched on May 20, 1919, at Sobral, in Brazil, which definitely proved Einstein's theory that light was *bent* in passing through a magnetic field.

Sir Frank Dyson himself has been on several of these expeditions to observe total eclipses. On one occasion, with a party of astronomers, he was taken to Morocco in a cruiser, the *Suffolk,* and he mentioned the fact that the present Admiral Beatty was then captain of the ship.

Sir Frank, through whose kindness this chapter has been made possible, is a Fellow of Trinity College, Cambridge, where he was Second Wrangler and Smith's Prizeman. He was Chief Assistant at Greenwich from 1894 to 1905, and then became Astronomer Royal for Scotland. In 1910 he went back to Greenwich as Astronomer Royal, a position which he has now held for twenty years.

MARINE BIOLOGICAL LABORATORY
WOODS HOLE
LIBRARY
MASS.

CHAPTER VIII

THE MASTER OF RELATIVITY

The Work and Life of Albert Einstein

IN 1831 Urbain Leverrier, a young man of twenty, was admitted into the Polytechnic School of Paris. Five years later he distinguished himself by writing some clever papers on chemistry and astronomy, with the result that he was offered the post of teacher of astronomy in the Polytechnic. He soon became known for his original work in this science, and was elected a member of the French Academy. His principal work was careful observation of the movements of the planets, especially of Uranus, which at that time was believed to be the last and outermost of the solar system, but Leverrier by his calculations decided that there must be still another planet farther out in space.

Shortly after Leverrier had written a paper announcing his belief in the existence of this planet, it was discovered by another astronomer, Gottfried Galle, of Berlin. Neptune, as it is named, though eight times larger than the earth, revolves at a distance of three thousand million miles from the sun, and is therefore so tiny a speck that it had hitherto escaped observation.

Now there is another planet which, like Uranus, has shown a slight irregularity in its movement. This is Mercury, the innermost planet of our system, a tiny body only three times the size of the moon; it circles around the sun in a year which is only eighty-eight of our days. It is so near the sun that it is very rarely visible to the naked eye.

Mercury's irregularity is a very small matter, yet the most careful observations extending over more than a century made it certain that this irregularity did exist.

The irregularity noticed was this. The perihelion of Mercury had advanced during the century between forty and fifty seconds of arc farther than it should have advanced.

Here it may be well to explain the meaning of perihelion. A planet revolving around the sun does not travel in a perfect circle, but in an ellipse—that is, in an elongated curve of which one axis is longer than the other. The perihelion of a planetary orbit is at one of the end points of the major or longer axis. The orbit of the planet, while always the same in relation to the sun, is not of course the same in space, for the sun itself is moving rapidly in one direction, dragging its attendant planets with it.

Now the question which puzzled astronomers was the cause of this irregularity in the perihelion of Mercury. For long they were of the opinion that there must be another undiscovered planet even nearer to the sun than Mercury, but search as they might this could not be found. Another suggestion was that there was a ring of cosmic matter distributed around the sun which disturbed Mercury's orbit, but this theory too was presently abandoned. It remained for Albert Einstein to supply a key to the puzzle of Mercury's curious behaviour, and this he did in a paper read in November 1915 before the Prussian Academy of Sciences.

What is Relativity? There is no need to be frightened by the word, which in itself is simple enough. There are comparatively few things in this world that are *absolute.* The number of people in a room, the number of coins in a purse, the number of bricks in a wall—these are absolute. But it is easy to find simple instances of relativity.

Imagine two brothers, Jim and Bill, each with one hundred pounds in his pocket. Settle both in London,

PROFESSOR EINSTEIN

Photo by Hoppé

and they are equally rich. Now transfer Bill to New York. Bill is no longer as rich as Jim, because prices in New York are higher than in London. Therefore the pound is not an absolute standard of wealth, but is relative to the place where it is to be spent.

Simpler still is relativity in direction. If you are in London you say rightly that York lies to the north, but if you are in Edinburgh York is south of you. The direction of every place in the world is relative to your position at the time of speaking.

Now with some trepidation we will go a little farther. In 1887 two scientists, Michelson and Morley, carried out an experiment by which they proved that speed causes contraction in a moving object. Take a rod moving at a very high speed. At first it is at a right angle to the line of motion, but as it moves we imagine it to be turned so that it lies along the line of motion. In its second position the rod is *shorter* than it was in its former. The speed of our planet in its journey around the sun is nineteen miles a second, and a rod travelling at this speed contracts one part in two hundred millions.

This seems so small a matter as to be hardly worth notice, for, applied to the earth itself, it means a contraction in its diameter of only two and a half inches; yet we may say that it is on the base of the Michelson-Morley experiment that Einstein has built up his tremendous and revolutionary Relativity and Quantum theories.

The experiment has been repeated by several observers since 1887, with great care and accuracy, and the contraction of moving bodies, now known as the Fitzgerald Contraction, is of enormous importance in modern physics.

The substance of our rod matters not at all. It may be wood or steel or lead. Whatever its substance its contraction is the same. Each time that you change the position of a foot-rule by holding it in line with the earth's movement it contracts by a two-hundred-millionth part of its length.

Nineteen miles per second seems a great speed, but we have all been travelling at that speed all our lives. Indeed, we have been travelling faster, for our planet has two additional movements—its spin on its axis, and the speed at which it is being carried through space by its master, the sun.

Please do not imagine that there is anything strange about this contraction. A rod of steel or wood may seem to us a solid object, yet it is of course nothing of the sort, for it is merely a swarm of molecules in active motion, separated one from another by quite considerable spaces. Every time that its position is changed changes are made in the magnetic forces which hold its particles together, and their delicate balance is upset. Really the wonder is not that there is a change, but that the change is so small.

Now you will begin to understand that measurement of length or distance is relative to direction.

Increase the speed of our planet. Make it one hundred and sixty-one thousand miles per second, and your rod, when turned, will contract to *half* its former length. So far as known, there is no planet which moves at such a speed as one hundred and sixty-one thousand miles a second, yet we have observed a nebula which is moving at one thousand miles a second, and if there were a planet in this system moving at the same speed its inhabitants would find that even this rate of speed was enough to upset entirely the accuracy of their measurements.

Now perhaps you will think that we are going to give you a simple explanation of Einstein's theories, and tell you why it is that he has come to the conclusion that space is "finite yet unbounded." We are sorry. We cannot do it. We have applied to several scientists who themselves do understand the Relativity and Quantum theories, but in each case the reply given has been the same: " It is impossible to explain Relativity except in terms of algebra." One went on to say further:

> This doctrine has to do with the relationship between physical and mathematical events and can therefore be explained only in mathematical terms. It is impossible to present it in any form which can be understood by those who have not a fairly advanced knowledge of algebra.

Still, Einstein's theory of space is not so difficult as the idea to which mankind has been accustomed for centuries—the idea that space is infinite. The human mind is baffled by infinity or eternity, but it does seem able to cope with Einstein's conception of curved space. It is possible that before the end of the present century boys and girls will understand Relativity and marvel at their grandparents' inability to do so.

Einstein's theory of Relativity, by the way, is not a reversal of Sir Isaac Newton's theory of gravity unfolded in his *Principia Mathematica* in 1687. Einstein's great intellect has simply capped Newton's theory with what he calls an " elliptic interval." While Newton's equations of motion state the true conditions of motion only approximately, Einstein's, as stated in his epoch-making paper of 1915, give them with absolute accuracy. Seated in his study, Einstein proved that Mercury's perihelion should advance forty-three seconds in one hundred years, thus solving at one stroke the problem that had been puzzling astronomers for so long.

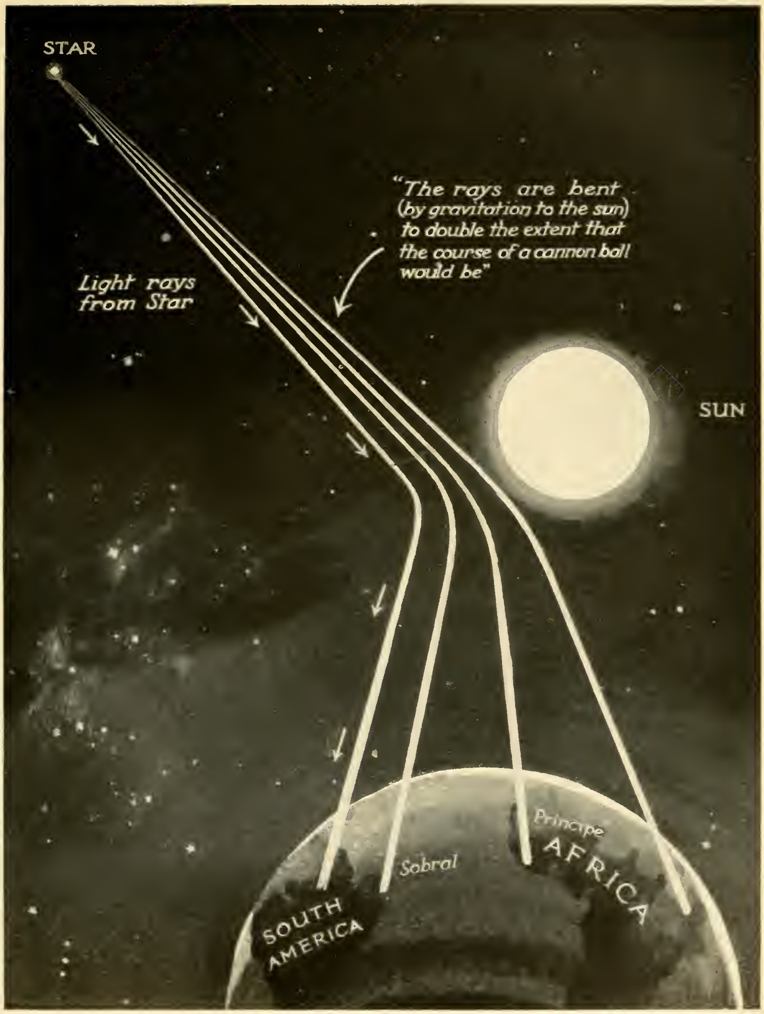
Einstein's achievement went farther still. During his investigations he came to the conclusion that light-rays do not travel in dead straight lines as had hitherto been believed, but that they curve under the influence of a ' gravitational field ' such as the sun. For the moment there was no means of proving this startling statement, which Einstein made with the calmness of conviction.

He knew that the opportunity would not arrive for nearly four years—that the world would have to wait for his proof until the total eclipse of the sun on May 29, 1919. Although, at the date of his lecture, all Europe was plunged in the horrors of the Great War, Einstein's statement caused a tremendous sensation and was eagerly discussed in all countries. Scientists everywhere awaited anxiously the time of test.

At last the War was over and the great day approached. Telescopes and cameras were ready at several points along the line of total eclipse, one point being a small island called Principe, off the coast of Africa. You will understand that it is only when the disc of the sun is obscured by the passage of the moon that the stars closest to the sun become visible, and so only then can they be photographed. These photographs would enable astronomers to learn whether the rays from stars passing close to the great bulk of the sun were actually bent. The proof would be secured if the distances of these stars, as recorded on the photographic plate, were greater than could be expected from their actual positions.

The eclipse came and passed, and within a few weeks Einstein's theory was proved to be perfectly correct. Newspapers all over the world proclaimed to their readers that light-rays did bend. A new truth had been established, and Einstein was rightfully acclaimed as the greatest and most original thinker of the twentieth century.

You may wonder why the phenomenon was not observed long ago. The reason is that the bend or deflection is almost infinitesimal. Einstein stated that it would be found to be seven-tenths of a second of arc. This corresponds to the thickness of a match seen at a distance of about nine hundred yards. One's wonder is divided between the brain that could calculate so tiny a deflection and the instruments that could detect it.


STAR
Light rays from Star
"The rays are bent (by gravitation to the sun) to double the extent that the course of a cannon ball would be"
SUN
SOUTH AMERICA
Sobral
Principe
AFRICA

HOW LIGHT IS BENT BY GRAVITATION

This diagram helps to demonstrate the Einstein theory of relativity. It shows the results of observations made on the occasion of the total eclipse of the sun in 1919, which proved the accuracy of Professor Einstein's great discovery.

Reproduced from "The Sphere" by permission

Einstein's later work is even less easily understood by the ordinary mind than the results which we have been describing, but he is always at work, and it is not too much to say that he has changed profoundly man's conception of the universe of which this earth of ours is a part.

Our readers may care to know something of the life-history of this astonishing man. He was born in Ulm, a city of Württemberg, best known for its wonderful cathedral, the spire of which towers to the great height of five hundred and thirty feet. One of his earliest memories is of his father showing him a compass. Albert Einstein was only five years old at the time, yet the metal needle swinging surely toward the north stirred in him a strange wonder. The house he lived in was small, but it had a charming garden, and the boy was very happy there. He did not show signs of his genius very early in life. In fact, he was so late in learning to talk that his parents were troubled, and even when he was big enough to go to school he was still a shy, quiet, rather solitary lad. Certainly he did not like his school, for it was run on regular Prussian lines, with masters stiff as drill sergeants. He seems to have worked well and steadily, but the only study for which he showed a real love was music. From his first school he went to the more advanced Gymnasium in Munich, and there he met a teacher who introduced him to Greek literature and to poetry, both of which attracted him.

About this time he became interested in algebra. An uncle of his lived in Munich, and one day Albert asked him: "What is algebra?"

The uncle's reply was: "Algebra is a great help to the lazy mathematician. If you do not know a certain quantity you call it x and treat it as if you do know it. In the long run you find what it really is." From that time onward Albert Einstein was never happier than when solving problems. He read book after book on mathematics and geometry, and shot so far ahead of his schoolmates that when he was only fifteen his mathematical master vowed that he was already fit to go to the university.

Then a great happiness came into his life, for his parents moved to Italy. The boy delighted in the beauties of the Apennines and walked for miles over the great and splendid hills. He loved the sun and the brightness that surrounded him. At seventeen he was admitted to the Technical School at Zürich, in Switzerland, where young men are trained as teachers, but the fact that he was not Swiss by birth prevented his gaining such a position, and he became a private tutor.

All through these years he was reading deeply in his spare time and discovering things for himself. Presently he obtained a position in the Swiss Patent Office as technical expert. This was very helpful, and his powers developed steadily, until in 1905 he began to publish papers on profound scientific subjects, which at once attracted the attention of thinkers and brought him a professorship at Zürich. In 1911 he was given a professorship at Prague, but he soon came back to Switzerland, of which country he has become a citizen.

One of the greatest of French physicists, Henri Poincaré, spent a year in struggling with Einstein's new theory of Relativity, and although he confessed that he found it extremely difficult to understand, he became one of the young man's warmest admirers.

Albert Einstein reached his fiftieth year in 1929. He is very happily married, and leads as quiet a life as the world allows him to lead. Allowed, we say, because it is the penalty of his fame that he is swamped with letters and requests for interviews. He has no laboratory—just a quiet upstairs room where he sits with a few books and a writing-pad and develops his theories. But he is no hermit, and he loves his violin, an instrument on which he is a fine performer. For an outdoor hobby he thinks there is nothing like sailing. As he says himself: " The only things that give me pleasure, apart from my work, are my violin, my sail-boat, and the appreciation of my fellow-workers."

He cares little for money and still less for titles or decorations. He does not even want praise. But he does value affection, and he has a very keen sense of fun.

CHAPTER IX

AN EXPERIMENTER WHO IS HIS OWN RABBIT

J. B. S. Haldane and his Adventures

SAYS Mr Haldane:

> When I was about twelve my father was very interested in diving. There was some talk at the time of the dangers of going down to any considerable depth, dangers which my father pooh-poohed. He said that any healthy boy could go down to forty feet, and he proceeded to try the experiment with me. My only training for this experience was a short sojourn in a compressed-air chamber, which taught me the necessity of 'swallowing' when pressure increased. If you do not do this you get a pressure on the ear drums which causes a most disagreeable crackling. Next day I was put into a diving suit and sent down to a depth of forty feet, where I stayed for half an hour.
>
> It was not altogether a pleasant experience, for the dress was too small and leaked horribly, and by the time I was pulled up I was wet to the neck and most bitterly cold.

Of all the scientists who have been good enough to grant interviews to the authors of this book, none began his scientific career at an earlier age than J. B. S. Haldane, for his father, the famous author of *Mechanism, Life, and Personality*, began to use his son for certain harmless experiments at the early age of four, and when the boy was no more than eight he was already taking notes for his father in the laboratory. At nine he went down coal-mines, for his father at the time was Director of the Doncaster Coal Owners' Research Laboratory. This was dangerous work, sometimes done under rotten roofs and in bad air and with one eye fixed on a canary in a cage, carried for the purpose of proving whether the air were breathable or not. On another occasion Haldane accompanied his father down a Cornish tin-mine. They were crossing a plank spanning an abyss when suddenly their light went out.

" Luckily," said Mr Haldane drily, " one has no sensation of giddiness in the dark."

An experiment in which he took part at a tender age was one which involved his being shut up in an air-tight box, a sort of coffin, that left only his head free. This was done with the object of getting a quantitative record of expansion when the subject was breathing certain mixtures of gas.

An adventure which amused him considerably was a short voyage in a French ship from Tilbury to Dunkirk. The vessel was full of rats; and the French authorities, who were in the throes of a plague scare, had asked Haldane Senior to test a new system for gassing rats. The forecastle was hermetically closed and the gas turned on. When it was opened again J. B. S. and a friend of his own age amused themselves by plunging into the still poisonous air and seeing who could collect most dead rats and cockroaches before choking.

J. B. S. Haldane has persisted in his habit of experimenting on himself. During the War he was employed on problems arising out of the ventilation of submarines. On one occasion he and a companion were voluntarily imprisoned in a steel cylinder seven feet high and five in diameter. The manhole was then closed and screwed down, and an engine began to suck out the air through a pipe. The air inside became very cold and filled with mist. In five minutes it had reached a pressure corresponding to that of a mountain-top twenty-two thousand feet high. Mr Haldane began to observe his own symptoms. He was breathing rapidly and deeply, and his pulse was one hundred and ten, but the breathing soon calmed down, and he felt better. But he began to wonder at his companion; his lips were purple, and he was making silly jokes and trying to sing. Haldane found that he could not stand without support.

His companion suggested a whiff of oxygen from a cylinder they had with them, and to humour him Haldane took a few breaths. The result was startling. The electric light seemed to become so brilliant that it looked as if the fuse would melt, while the noise of the pumping engine apparently increased fourfold. At the end of half an hour the pumping ceased and the prisoners were set free, none the worse save for a slight headache. But Mr Haldane states that his notebook, which should have contained records of his pulse beat, was full of statements—very illegible statements—to the effect that he was feeling much better, but that he believed his companion to be drunk.

Oxygen, it seems, is the only cure for mountain sickness. General Bruce's party carried oxygen cylinders during their ascent of Mount Everest. But the effect on those who take oxygen under such conditions is to make them oddly quarrelsome. One of the few residents at the summit of Pike's Peak, an American mountain greatly favoured by the tourist, is a sheriff who finds plenty of work in dealing with quarrelsome visitors. Above sixteen thousand feet oxygen is almost a necessity; it was always supplied during the War to the crews of high-flying bombing machines and airships. Oxygen, says Mr Haldane, has a great future as medicine, and properly administered it may halve the death-rate from pneumonia. But it must be given continuously, perhaps for as long as three days and nights on end, and it must not be breathed pure, for in that state it is a slow poison.

A subject in which Mr Haldane takes great interest is 'water-poisoning.' It sounds perhaps rather absurd to talk of poisoning by pure water, yet this is quite possible. The writer was once out fishing on Dartmoor on a blazing hot day. He became extremely thirsty, and, finding a spring of ice-cold water welling from the hill-side, drank, not wisely, but too well. In a short time he collapsed in agonizing cramp.

About the hottest place in England is a deep coal-mine. There is one under Salford nearly a mile deep, with a temperature so torrid that the men work in boots and bathing drawers, and drip with sweat during the whole shift. It is on record that one man lost eighteen pounds' weight in the course of a shift. So long as these men did not drink more than a quart of water during a shift no harm came to them, but if this amount was exceeded—and of course it often was—they suffered from appalling cramp, sometimes in the stomach, sometimes in the back or shoulders. The reason, as explained by Mr Haldane, was that they had taken too much water for the salt concentration in their blood. Blood, as we all know, is as salt as sea-water, and large amounts of fresh water alter its content.

The miners were then provided with drinking-water in which a certain amount of salt had been dissolved. To anyone less thirsty than they it would have been a nasty beverage, but they drank it by gallons and asked for more. And now there is no more cramp and very much less fatigue. The cramp of stokers, and of gas- and iron-workers, can be prevented in the same way.

J. B. S. Haldane is a bio-chemist—not a doctor, but one who takes a part in developing or creating remedies for diseases. As he says himself, a bio-chemist provides chemical splints for damaged organs. Now most people have an idea that all drugs are tried out upon animals such as dogs, rabbits, guinea-pigs, and rats. It would surprise them to learn how often the chemist tries experiments on himself, how often he acts as his own rabbit.

On one occasion Mr Haldane wanted to know what happened to a man when he became very acid or very alkaline. Many of us know by unpleasant experience what it is to be too acid. The acid stored by the digestive organs is hydrochloric, and anyone who gets too acid suffers from that peculiarly distressing form of indigestion known as heartburn. This actually has nothing to do with the heart, but the sensation is very disagreeable, and the commonest and most obvious remedy is an alkaline substance such as bicarbonate of soda.

Mr Haldane and one of his colleagues made themselves alkaline by over-breathing and by eating up to three ounces of bicarbonate of soda. The use of bicarbonate for this purpose is obvious enough, but the resource of over-breathing is less so. We all know that the lungs supply the body with oxygen, and remove the carbonic acid which is formed by the process of digestion. If you over-breathe you get rid of too much carbonic acid, which is the factor regulating your rate of breathing. You blow it all out, and the results are curious and unpleasant. You get ‘ pins and needles ’ in your hands, feet, and face, and if you persist the hands become stiff and the wrists bend. On one occasion, after an experiment in over-breathing, Mr Haldane suffered for no less than an hour and a half from spasms of hands and face. When conducting an experiment of this kind the experimenter's chief trouble is that he is very apt to fall sound asleep, and so he requires a helper to prod him into wakefulness again.

These experiments threw much light on a disease called tetany (not tetanus, which is quite different and much more dangerous), of which the symptoms are cramp of the hands, feet, face, and sometimes of the windpipe.

So much for making oneself alkaline; achieving great acidity was a much more difficult and dangerous matter.

Sitting in an airtight room and so increasing the amount of carbonic acid in the blood was one way; this ended in a very bad headache, but the result was only temporary, and Mr Haldane wanted something which would keep him acid for several days at a time. The obvious method was to drink a large quantity of hydrochloric acid, but hydrochloric acid is a violent poison; taken pure, it will not only burn out one's inside, but actually dissolve one's teeth. The strongest solution that can safely be taken is one part in one hundred of water, and even a pint of that is too stiff a dose for most people.

After considering the matter our experimenter decided upon eating a quantity of ammonium chloride, which would break up inside the body, liberating hydrochloric acid. He took an ounce a day for two or three days, and after this, he remarks casually, he remained breathless for another two or three. His blood lost ten per cent. of its volume, his weight dropped seven pounds in three days, and his liver went very wrong. This experiment, which Mr Haldane has described in a paper entitled " On being One's Own Rabbit," had valuable results, for since it was carried out babies suffering from tetany have been given small doses of ammonium chloride, and the trouble can then be cleared up within a few hours.

We have described these experiments at some length because it is worth while to point out that bio-chemists do not depend upon animals for the testing of their new theories, but are constantly making tests upon themselves. You may possibly have heard of the so-called ' Poison Squad ' at the Federal Bureau of Chemistry in Washington, U.S.A. It consists of volunteers—all expert chemists—who test various adulterated food products seized by Government agents, and eat them under the inspection of doctors who are experts in toxicology (the science of poisons). More than one of this devoted band has become seriously ill, and one, Robert Vance Freeman, died as the result of absorbing poisons from adulterated food.

The eight people who ate wild-duck paste sandwiches at Loch Maree in 1922 all died of a kind of paralysis which began in their eyes and spread until they were unable to breathe. The poison in this case came from a bacillus called *botulinus*. This, says Mr Haldane, is the most poisonous of all known substances which can be taken by the mouth—so deadly that one man could carry enough of it to poison the entire human race. This poison is made by a bacillus which can only live where there is no oxygen, and is therefore found chiefly in tinned foods, but occasionally in the interior of sausages and hams. Happily it is killed by cooking.

It was Professor Bruce-White of Bristol University who solved the riddle of the death of these unfortunate people by detecting the poison. While every large town in Britain has its own analyst who examines suspected foods, the more difficult analyses are largely in the hands of half a dozen men at the Bristol Laboratory. They are inundated with samples of cheese, ham, brawn, meat pastes, tinned salmon, and other foods that are under suspicion. In some cases these chemists do not hesitate to taste the suspected samples, and on one occasion Professor Bruce-White made himself very ill by tasting some Canadian cheese which had caused poisoning outbreaks at Dover and at Warrington.

The list of men and women who have risked their lives for Science—and often lost them—is a very long one. One of the most famous was the late Professor Maxwell Lefroy, whose principal triumph was the defeat of the death-watch beetle, which does so much harm to old buildings. It was during a search for a new form of poison gas to destroy the house-fly that he was killed. That was in 1925. Earlier in the same year he had been very nearly killed. When he recovered he was asked what led up to the accident. His answer was: " I am surprised and sorry that the matter received so much publicity, because such accidents are part of the normal daily risk of our work and we do not think very much about them."

A splendid example of devotion was given by an English nurse, Miss Mary Davies, at the American hospital at Neuilly, in France, during the War. Dr Taylor, of the Imperial Cancer Research Institute, had been experimenting with a quinine preparation for the cure of that terrible malady gas-gangrene, but in using guinea-pigs had been unable to obtain definite results. He needed a case of gas-gangrene not complicated by other forms of infection.

Nurse Davies, who had studied at the Pasteur Institute, had seen some two hundred fatal cases of the disease. Without saying a word to anyone, she took a room near the hospital, and two days later sent a note to Dr Taylor begging him to come. He came and found that she had given herself an injection of the culture of gangrene which he himself had been using. Within two hours symptoms of gas-gangrene developed. The doctor at once injected his quinine preparation, and in twenty-four hours the patient was out of danger. The risk taken by Nurse Davies was terrific, but it was indirectly the means of saving many lives.

Another nurse, Miss Clara Maas, of the American Ambulance, gave her life in a similar experiment. She allowed herself to be bitten by a mosquito infected with yellow fever. Though treated with serum by Dr Caldas, she died. She was one of several people who allowed themselves to be infected with the same deadly disease. Of these, three died, but it is largely owing to their self-sacrifice that yellow fever, once the plague of the Southern States, has now been practically conquered.

Dr Houston of the Metropolitan Water Board is another who took a grave risk for the sacred cause of Science, for he drank raw Thames water containing typhoid bacilli. Experiments had proved that ' cultivated ' strains of the microbe possessed great vitality, but tests with bacilli taken direct from typhoid cases showed that these were not so hardy. The ' wild ' microbe is not always easy to obtain, but Dr Houston was able to get a supply from a sufferer who had himself infected forty different persons. The bacilli perished rapidly when placed in samples of raw Thames water, but Dr Houston regarded the result as a negative test and decided upon a positive one. He therefore drank half a pint of the infected water, which at a rough estimate contained two hundred and eighteen million typhoid bacilli. We are happy to be able to add that he was none the worse.

Among the many queer experiments carried out for the purpose of testing scientific theories was one conducted at the London Hospital, where a medical student allowed himself to be suspended by the heels from a hook in the ceiling. Professor Leonard Hill had been conducting a series of experiments on blood pressure, and wished to discover how far the healthy human heart is able to nullify the effect of gravity on the blood streams of the body.

Professor Hill said:

> When a healthy man stands upright the blood pressure in the vessels of the neck is about equal to a column of one hundred and twenty millimetres of mercury. The pressure in the vessels of the lower leg is, however, much higher on account of the actions of gravity on the vertical column of blood, and is equal to one hundred and ninety millimetres of mercury. In theory if a man is turned upside down the leg pressure should fall to one hundred and twenty and that in the neck rise to one hundred and ninety. To find out if this really did happen we suspended a student for three minutes from the ceiling. We found that, although the leg pressure dropped to about

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Photo by Vaughan and Freeman

fifty, there was no corresponding rise in pressure in the neck and arm vessels. In other words, the healthy heart was able to nullify the effect of gravity.

There is no special risk in hanging upside down for three minutes—nothing more is involved than a certain amount of discomfort. The sleepless tests which were conducted in Washington in 1925 must have imposed a more severe strain upon the students who carried them out. Eight undergraduates volunteered. Six completed sixty hours without sleep and two completed eighty-five. The object was to test the change in mental and physical condition caused by lack of sleep.

Every week there are similar instances of self-sacrifice in the interests of Science, but as a rule we hear nothing about them. They are taken as a matter of course by scientists of all nations, and even when news of some desperate experiment leaks out the names of the experimenters are usually concealed. It is known, for instance, that several British laboratory workers inoculated each other with living cancer germs in order to test the theories of Doctors Gye and Barnard, but the names of these astonishingly brave men were never made public.

Amateur as well as professional scientists have shown immense courage in their work. Mr Haldane mentions one of these in a paper called *Scientific Research for Amateurs*. He describes the swim of the young Frenchman Norbert Carteret through the cavern of Montespan. Here was a stream flowing out through a cave in which had already been found traces of a long-vanished race. Flint tools and bones had been discovered, and it occurred to Carteret that if he could force his way up this stream he might make important finds. Carrying matches and candles in a waterproof case, he waded up the swift, ice-cold river to the spot where the roof met the water; then after taking a long breath he dived and swam desperately against the strong current until he found air once more above him.

He was now in a section of the cave which had been sealed off from the world by water for many thousands of years, and, walking, swimming, and diving, he carried on for more than a mile, when once more he came out into daylight. The results were of the greatest importance, for he discovered a number of rude statues of unbaked clay, of a type hitherto unknown. Superb powers of diving and great courage were needed for this really amazing venture.

Research of the kind mentioned in this chapter is now being carried on in every part of the world, and by people born in every continent. Sir Ernest Rutherford, whose story is told elsewhere in this book, was born in New Zealand; Bose is a Hindu; Hata, the man who helped Ehrlich in his great medical discoveries, was a Japanese; Mendeléeff and Metchnikoff were Russians; Banting, of insulin fame, is Canadian; while small countries such as Denmark and Switzerland, and new countries such as the Argentine Republic, are all producing good men, ready to suffer as well as work in the cause of Science.

But we have wandered quite away from the original subject of this chapter. Mr Haldane is a man of many parts, and his interests embrace plant as well as animal life. One of his pursuits is the genetic study of plant life, and the writer found him in the large garden where he is the head of the Genetical Department.

This garden, at first sight, resembles that of one of those advanced seedsmen who work on the production of new varieties of fruits and flowers, yet very soon a big difference is discoverable. While it is true that a large number of new varieties of plants are produced, many of these are quite unfit for sale. For instance, there is a large glass-house devoted entirely to primulas; it contains about one hundred and fifty different varieties all obtained from the original *Primula sinensis* which came from China about a hundred years ago. Some of these are very beautiful, others are freaks. One, for instance, has a great bunch of leaves around each head of blossom; in another the flowers are represented by small green knobs. These crosses are being studied from the point of view of pure Science. There is a laboratory in the garden, and here new varieties are dissected, their colouring matter analysed, and much information obtained which will serve both Science and the scientific grower.

In another house there were plum-trees in full bloom. The windows of this house were carefully screened with fine wire gauze so as to prevent any insect entering, for this might cause the pollination of one bloom from another. These blossoms were being artificially crossed, and each branch bore a separate label showing the exact nature of the crossing.

Odd discoveries are made now and then. One concerns the crocus and an aphis. If there is one form of insect more pestilent than another in the eyes of the gardener it is the aphis or green fly. It ruins roses, destroys broad beans, and it will settle like a plague on everything in the greenhouse. Ask the average gardener if he can imagine any use for the green fly and his language will be pungent enough to shrivel the leaves; yet one of these aphids has been proved to have a real use, for through it certain crocuses assume that beautiful marbling which is so greatly admired and so difficult to obtain. Now that the secret is out marbled crocuses are likely to become much more plentiful and cheaper than they have been in the past.

Like all or most scientists, Mr Haldane is a very modest man.

"I am," he said, "a rotten observer. If I have any merit it is that of being able to devise experiments which will clear up problems." He has a great admiration for the manual skill of men like Aston, who matches the great billiard-player Lindrum in his dexterity.

Mr Haldane has another talent of which he did not speak, an invaluable gift of putting down the things he has observed in English which the layman can not only understand, but enjoy. The essays contained in his book *Possible Worlds,* from which he has kindly allowed information to be drawn for this chapter, are as interesting as any romance, and delightfully written.

CHAPTER X

HOW THE CHEMIST WENT FARMING

Sir Daniel Hall and his Experiments

A POET has spoken of " dead earth." Take up a handful of soil from your garden and examine it. You are holding a very large number of particles of rock broken up by frost and rain, and mixed with a certain amount of decayed or decaying animal and vegetable matter. Apparently it is all dead enough, yet put a pinch of that soil under a powerful lens and you will see millions of living creatures, which multiply with immense speed. These are bacteria, and the top layers of the soil are full of them. Three or four feet down, however, they almost cease to exist, and below a certain depth the soil is dead indeed.

Without these tiny atoms of restless life no plant could grow. Although they are invisible to the naked eye, they are precious beyond gold, for without them our planet's surface would be as dead as that of our satellite the moon.

But plants, you say, do not live on bacteria. That is so, yet certainly they cannot live without them. Put a cartload of stable manure on your garden in the spring, and how much of it is visible when you do your next winter's digging? Practically none, and you say the plants have used it.

But a plant cannot eat manure. It can only feed upon it after it has been converted into something else. The agents for that conversion are the tiny living creatures named bacteria. They are almost incredibly small. Most of them average between one twenty-five-thousandth and one fifty-thousandth of an inch in diameter, yet they multiply so fast that under perfect conditions one of them might in a day become the ancestor of 280,000,000,000,000.

Bacteria are responsible alike for the flavours of butter and tobacco and for the smell of a dead mouse. Their most important job is the breaking down of manure and other organic substances into food for plants. One race of bacteria turns the dead plants into humus, another into nitrate and into the other substances on which plants live. Even such tough stuff as wheat straw is broken down by them and converted into plant food.

One of the things that scientists have found out is exactly what plants do live upon. They have discovered precisely how a plant feeds and under what conditions of food, moisture, and warmth it most quickly reaches its full growth. The first step in this direction was the analysis of plants.

Take a living plant and reduce it to its elements; it will be found that water is its most important constituent; next comes carbon. Of the dry matter of the plant fully half is carbon; oxygen and hydrogen compose most of the remainder, with a certain number of other elements, one of them being nitrogen. The amount of nitrogen is small, being only about one-fiftieth of the dry matter, yet nitrogen is so important that no plant can exist without it. The remaining ash is formed of a number of other elements, phosphorus, silicon, chlorine, and the metals potassium, sodium, calcium, magnesium, iron, and manganese.

Interesting, no doubt, you will say, yet crops were grown long before people had any knowledge of these facts. Our ancestors also used manures to make their crops grow. That is true. Such things as dung and leaf mould, chalk and marl, have been used from time immemorial, but they were used blindly.

So far as we know, the first artificial manure to be used

SIR DANIEL HALL

was bones. Bones make useful manure because of the phosphorus they contain, but bones lie in the soil a very long time before they rot down and form plant food. An important discovery of the nineteenth century was that of the chemist Liebig, who found that bones when treated with sulphuric acid made a splendid plant food; an almost greater discovery was that of Henslow, who found that coprolite, a mineral found first in Cambridgeshire, could be used like bones for making superphosphates. Of this one manure the world now makes and uses more than six million tons a year.

The three foods which plants need most are nitrogen, potash, and phosphorus. Without these foods our gardens and fields would be deserts, and we should starve. Formerly the farmers got enough of these substances from the old-fashioned manures, but during the past one hundred and fifty years the population of the world has nearly trebled. In the year 1780 the people of this planet numbered only a little over six hundred million; to-day it is reckoned that there are more than seventeen hundred million, and if Science had not stepped in to help the farmer these multitudes would not have enough food to eat.

There are many ways in which the scientist has helped us, but none is more important than his provision of artificial food (fertilizers) for our crops. It was in England that agricultural science had its birth, and Englishmen have done a great deal to increase the world's food-supply.

Most people have heard or read of the Rothamsted Experimental Farm, the most famous place of its kind in the world. Rothamsted, which is near Harpenden, in Hertfordshire, belonged to John Bennet Lawes, who was born in 1814. He was educated at Eton and Oxford. Experiments in chemistry were his favourite amusements as a boy. In 1834, when only twenty, he took up the management of the home farm at Rothamsted, comprising about two hundred and fifty acres, and one of the first things he did was to turn an old barn into a laboratory.

Lawes began his experiments by planting wheat, oats, etc., in pots, feeding them with different manures and noting how they grew. One of the first new manures he used was animal charcoal, which was then a waste product. He found that it was much more efficient if first treated with sulphuric acid, and this led to the discovery of superphosphate of lime, which worked wonders on the turnip crops.

Lawes found that he needed a trained chemist, and engaged Dr J. H. Gilbert. The two worked together for fifty-seven years, and few partnerships were ever of so much service to mankind. For one great thing which they did was to work out the proper rotation of crops. No gardener dreams of planting cabbages in the same bed two years in succession. Cabbages take so much out of the soil that it does not pay to grow them on the same plot twice running. It is better to follow with peas or potatoes, and to grow cabbages on another bed. That had been known for a long time, but Lawes and Gilbert showed exactly what a crop of wheat or barley or turnips took out of the ground, and why beans should follow wheat. They also worked on pasture, showing exactly what effect different fertilizers had on the milk yield of cows grazed on fertilized and unfertilized fields, and the value of differently treated grass lands for fattening stock. The problem of what the landlord ought to pay to an outgoing tenant as compensation for unexhausted manures was another of those worked out at Rothamsted.

For his services to agriculture Lawes was made a baronet, and honours came to him from all over the world. He lived to be eighty-five, and before he died set aside one hundred thousand pounds so that the Rothamsted Farm experiments could be continued. Sir Daniel Hall has written a book on these experiments, which is full of interesting tables showing the different crops given by the use of different manures. For instance, hay. Hay grown on unmanured land at Rothamsted over a period of forty-seven years averaged only twenty-three hundredweight to the acre. Hay grown with a complete mineral manure but with no nitrogen gave thirty-nine hundredweight to the acre, but hay on a plot fully manured ran to no less than sixty-four hundredweight per acre.

One patch of land at Rothamsted has been cropped for years without being given any fertilizer at all, and the nitrogen loss has been noted. The nitrogen goes on dwindling year by year. Another field has been allowed to lie fallow for twenty-five years. The self-sown grasses and weeds are never taken away, but allowed to rot where they lie. This land is improving, and the amount of nitrogen contained in it is increasing. What is happening is that a kind of bacterium called the azotobacter is able to work among the dying vegetation and to *fix* a certain amount of nitrogen from the air.

A few years ago efforts were made to ' domesticate ' the azotobacter and inoculate soil with it. But as yet this experiment has not been very successful, and Sir Daniel Hall says, " The picture of the farmer carrying the manure for a field in his waistcoat pocket and applying it with a hypodermic syringe is still a vision of the future."

Air, as we all know, consists largely of nitrogen gas, and since supplies of nitrogen from other sources have been running short the scientists have invented ways of getting nitrogen from the air for use on the land. In the great plant at Bellingham, near Darlington, thousands of tons of nitrates are manufactured yearly from the air by an electrical process; in Norway and Germany there are large factories for the same purpose. At Bellingham nitrate of ammonia is combined with chalk into what is called nitro-chalk, which is a most valuable fertilizer.

Fertilizers, though immensely important, are not the only concern of the agricultural chemist. For instance, the texture of the soil makes a deal of difference to the growth of crops. Every gardener knows the value of a fine tilth—that is to say, of breaking up and powdering the soil properly before sowing his seeds. Sir Daniel and others have tested various soils and shown that sandy soil, which the farmer calls light, is actually heavier than heavy clay. The latter weighs only just over sixty-six pounds per cubic foot, while the sand weighs seventy-nine pounds. The reason for the difference is that there is more air space between the very small grains of the clay than between the heavier grains of the sand.

Again, the farmer talks of ‘ warm ’ and ‘ cold ’ soils. Soil temperatures do vary greatly, for a well-drained loam absorbs more heat than a wet, heavy clay or a pale chalk. Experiments set forth by Sir Daniel in his book *The Soil* show how land should be treated in order to gain the greatest share of the sun’s warmth, and the temperatures required for the best growth of various plants. Wheat, for instance, begins to grow at a temperature only eleven degrees above freezing-point; it makes its greatest growth between eighty-three degrees and eighty-four degrees; but if the temperature rises above 108·5 growth ceases altogether. The melon refuses to start growing until a temperature of 65·4 degrees has been reached, does best at 91·4, and refuses to grow in a heat above 111 degrees.

The farmer or fruit-grower has always known that certain soils are better than others for certain crops. For example, the Vale of Evesham grows the best plums in England, while Kent has soil best fitted for cherry orchards. The agricultural chemist has pointed out the reasons for these peculiarities, and has helped the farmer to find the best soils for such new crops as sugar-beet.

Let us turn from the soil to the plant. In another chapter of this book we have given some account of the work of Luther Burbank, who has tamed wild plants and improved cultivated varieties. Plant-breeders have done an immense amount of good work in evolving new strains of common crops, so that the farmer of the twentieth century has a far wider variety from which to select than had his father. But even more valuable has been the work done in producing varieties of disease-resisting plants.

'Rust' is the great foe of the wheat-grower, and it has been reckoned that in the past at least fifteen per cent. of the world's wheat crop was lost through this one disease. The spores travel on the wind and so cross whole continents. Professor Biffen is one of those who have evolved new strains of wheat able to withstand the attacks of rust. He has also produced wheats that are strong in the stalk and therefore not so liable as the older varieties to be 'laid' by heavy rains. This is important, for at present no farmer dares to fertilize his wheat-fields to the full extent—that is, to get the utmost possible crop—for if he did so the wheat would grow so tall and the ears would be so heavy that a summer thunderstorm would flatten out the whole field and make harvesting a most costly and difficult matter.

Australia is now growing large quantities of wheat on land where the rainfall is small and uncertain. There Farrer has bred wheats suitable for these dry conditions. In Canada Dr Charles Saunders has obtained fast-growing, quick-ripening wheats which have added millions to the value of Canadian soil. It is not so long ago that the forty-ninth parallel—that is, the northern limit of the United States—was regarded as the northern limit of the wheat-field. Farmers who started grain-growing in Canada were looked upon as lunatics.

'Marquis' wheat, originated by Dr Saunders, has changed all that, and to-day farmers are growing this particular wheat well above the fifty-third parallel of northern latitude—that is, more than four hundred miles north of the line fixed fifty years ago. Within less than a man's lifetime Canada has become the granary of the Empire, and each year sees the wheat-line creeping farther and farther north. In 1929, we are told, wheat of a new variety called ' Garnet ' was actually ripened in Alaska.

Another country which has a large wheat-belt is India, and there Mr and Mrs Howard are breeding new varieties to satisfy the requirements of the local growers.

The potato becomes more and more important as an article of food both for man and beast. But the potato is liable to various diseases, the worst being the terrible wart disease, for which there is no known remedy. Here again the plant-breeder has come to the rescue by breeding new varieties of immune potatoes—that is, potatoes that do not take the disease at all.

Investigations made at Rothamsted have shown that different varieties of potatoes vary greatly in their feeding value, some containing as much as twenty-six per cent. of dry matter, others only nineteen per cent. A ton of the former are therefore worth twenty-eight hundredweight of the latter from the point of view of food. It is easy to see how valuable this discovery is, say, to a pig-farmer.

Seventy or eighty years ago nearly all gardeners saved their own seed. They had to, for the seeds from the seedsmen were shockingly bad. In fact, there was actually a big trade in dead seeds, that were no more use than dust or sand. Even if the seed was good it was mixed with all sorts of pestilent weed seeds which came up with it and fouled the land. One of the many debts that the farmer and gardener owe to the scientist is the fact that nowadays seed bought from any reliable seedsman is live and clean.

All seeds nowadays are tested scientifically before being sent out. The process is this. A pinch of seed is sprinkled on a small sheet of soaking wet blotting-paper and put into the germinator, a sort of oven in which exactly the right degree of warmth is kept up. Within a few hours or days a peep into the germinator will show that the seed in bulk is all right if its representatives have 'passed their exam.' and are sprouting gaily. Thus the exact proportion of germination is ascertained—that is, how many seeds in each hundred can be expected to sprout.

Nearly thirty years ago Professor S. Lestrom, of Helsingfors University, began experiments to find out the effect of treating growing plants with electricity. During 1902–3 he had experimental fields near Newcastle in connexion with the Durham College of Science, in Germany near Breslau, and in Sweden at Alvidaberg, where he grew plants of different kinds under electrical treatment. He came to the conclusion that strawberries showed a considerable increase in yield under this treatment, wheat a much smaller yet perceptible increase, potatoes and beet still less. He declared that electrical treatment was useful on well-tilled land, but of no value on poor, unfertilized soil.

Since that date many experiments have been made in what is called electro-culture. In 1921 electrical stimulation of plant growth was tried at Rothamsted. Currents of fifteen thousand volts were passed over growing barley on a network of wires suspended ten feet above the ground. Similar experiments have been made at Salford Priors, near Evesham, where a small grant was made by the Board of Agriculture toward the cost of the apparatus.

There are three ways of using electricity to help the growth of plants. One is to sink plates in the ground and gently shock the roots of the plants growing between them. Lord Kelvin, hearing of this plan, smilingly suggested that perhaps it was the turning up of the soil in order to sink the plates that did the plants good. A second method is to turn night into day by means of electric light. This was tried at the Royal Botanic Gardens by the late Mr Thwaite, and it worked well. At the end of four days tomato plants grown under the electric light were four inches higher than those in another house where the plants had not been so treated, while chrysanthemum plants thus treated were two inches taller.

The third and more usual method is to run overhead wires above the field or plot and pass the current through these at a high potential. When there is no wind one can hear the fizz of the charge coming off the wires, and in the dark there is a faint glow visible.

The writer asked Sir Daniel Hall whether electrification was going to help the farmer. He answered that he did not know. That passing a current through overhead wires does increase the growth of the plants beneath the wires seems beyond doubt, but at present the cost of the installation is very heavy, and the benefit obtained does not appear to compensate for the money spent. In any case, electricity will not serve as a substitute for fertilizer. As Sir Oliver Lodge once said: " Stroking a plant is not equal to feeding it."

But if electro-culture is still more or less in the air, the electric farm—that is, the farm run by electric power—is a notable success. There are already some eight hundred of these farms in the country. At a small two-men farm of seventy acres, where the cows are milked by machinery, the saving over hand-labour is eleven pounds thirteen shillings a year. On separating the milk the saving is five pounds sixteen shillings. On pumping water the saving is six pounds eight shillings and fourpence, and on chaff-cutting nearly two pounds.

But the largest increase of profit is in the electrified poultry-yard. In a hen-house lighted and heated by electricity the yield of eggs in winter is increased fifty per cent., while growing chicks treated with ultra-violet rays are at nine weeks old twice as heavy as others grown in the ordinary manner. Incubators can be worked safely and economically by electricity, and the electric brooder has been proved a great success.

Another interesting use of electricity in farming is its use for making hay without sunshine. As soon as the grass is cut it is stacked in the rick, with iron cylinders placed in proper positions according to the size of the rick. Air from an electric fan is then forced through the rick for about an hour a day for nine days, and hay of excellent quality is the result.

Within the past one hundred and fifty years the death-rate among the people of this country has fallen from seventy per thousand to fewer than fourteen per thousand. This is due to the medical scientists who have discovered ways of preventing and curing infectious diseases such as smallpox, typhus, scarlet fever, and diphtheria. In similar fashion the agricultural scientist has cut down the death-rate among our domestic animals. There is now less foot-and-mouth disease in Great Britain than in any other country, while such diseases as swine fever and anthrax have been checked. At New Haw, near Weybridge, the Ministry of Agriculture has a research station, the purpose of which is to investigate the diseases of livestock, to find out how they are caused and how they can best be prevented. Diseased animals arrive there from every part of the country, and are kept under observation. Many of these diseases are extremely infectious and can be communicated to human beings.

Seven scientists are in charge of this station, where all sorts of curious experiments are carried out. For instance, some of the ground is deliberately poisoned, yet on this land fat turkeys roam quite happily. The sheds at New Haw are built of corrugated iron with a framework of metal. When it is necessary to disinfect a shed it is filled with straw which is soaked in petrol and fired. The shed is red hot when the fire dies down, and it is fairly safe to say that the germs have all been destroyed.

Sir Daniel Hall, who has very kindly provided most of the material for this chapter, was originally a young chemist interested in gardening. In 1890 he began his career by lecturing on matters of interest to farmers. In 1894 he was appointed first principal of the well-known agricultural college at Wye, and, as he says, he has grown up in the movement.

He became a director of the Rothamsted Experimental Farm, about which he has written a most interesting book, and during the War he was brought by Lord Prothero into the Ministry of Agriculture. At present he spends a good deal of his time in the interesting garden at Merton where Mr J. B. S. Haldane carries out his plant experiments.

Some of the data in this chapter are the result of the work of Mr R. Borlase Matthews, of Greater Felcourt, himself a distinguished scientist, to whom also we offer our acknowledgments.

CHAPTER XI

SOLVING THE RIDDLES OF SPACE

The Achievements of Sir Oliver Lodge

ON a December day in 1904 a tall man in a long brown overcoat stood in a courtyard of Birmingham University. The air was thick with one of Birmingham's worst brand of winter fogs; not even a London 'particular' is thicker than the really bad Midland fog. The tall man was Sir Oliver Lodge, Principal of Birmingham University, who was engaged in examining certain strands of wire which passed upward and vanished in the impenetrable gloom a few feet overhead.

Presently there came from somewhere near by the vicious crackle of a powerful electric discharge, and great jagged sparks shot to and fro between the spherical terminals of an apparatus in the research laboratory outside which Sir Oliver was standing. Men pulled the terminals apart, and as the discharge was transferred to the outside wires there came from above a sharp fizzling like the sound of water dropping on red-hot metal.

Then a strange thing happened. The solid fog-bank thinned. There was no wind to drive it away. It simply thinned, and the outlines of the lofty University building gradually developed like the image on a photographic plate. The fog turned to cloud, the cloud to mist, and high overhead there became visible the insulators in which the wires terminated. When the current was shut off the biting fog crept back and in a few minutes filled the space which had been so strangely cleared. A second experiment of the same kind was made a little later at Liverpool. One discharging pole was erected, and a thick fog was quickly cleared for a distance of sixty feet all around.

For centuries fog has been one of man's worst enemies, and for many years scientists have discussed ways and means of fighting it. In 1870 Professor Tyndall showed that a dust-free space was formed over a hot body such as a red-hot poker. At first it was thought that the heat simply burned up the dust particles or that the rising currents of air blew them away, but a little later Lord Rayleigh proved that the explanation was not as easy as this. In 1883 Sir Oliver Lodge took up the problem, and with the help of the late Professor Clark he proved that what actually happened was a bombardment of the dust particles by molecules, and further experiments proved that this is an electrical action.

What is a fog? It is caused by particles of dust on which, when the air is still, condense tiny drops of water-vapour. Smoke on one side, mist on the other, and a town fog is a combination of the two. Electrify a cloud and it turns to rain. Sir Oliver Lodge proved similarly that if you electrify a fog the dust or smoke in it is precipitated—it falls to the ground. So came about the interesting experiments which we have described; these prove that if the supply of electric power be sufficient, even the densest fog can be cleared away.

From his student days Sir Oliver Lodge has taken a keen interest in weather, especially in electrical phenomena, and one of his most interesting books, written in 1892, deals with protection against lightning. (It is called *Lightning Conductors and Lightning Guards*, and is published by Pitman.)

The lightning conductor was in existence, of course, long before Sir Oliver's time, for the first was erected by Benjamin Franklin on his own house in Philadelphia in the year 1752. Most of us know something about lightning conductors; at least we know that they are made of

SIR OLIVER LODGE, F.R.S.
A recent portrait.

copper or iron with a sharp point at the top, and that the lower end is connected with a metal plate buried in damp ground. The object is twofold: first to drain away the electricity from passing clouds and so render them harmless; secondly, when this is impossible, to receive the flash and convey it to earth without harming the building to which the conductor is attached.

For many years after Franklin first used it the lightning conductor was not generally adopted, but by the middle of the last century it was used on all church spires, factory chimneys, and similar tall buildings, and it was supposed to afford complete protection. But while conductors doubtless saved many lives and buildings, protected buildings were sometimes struck.

Several of these are mentioned in Sir Oliver's book. There was an instance at a house in Wavertree, where lightning struck a church which had a conductor, and at the same time a gas pipe was melted in an underground cellar of the house opposite, and the gas was fired. On May 14, 1889, Mangalore Lighthouse, off the east coast of Madras Province, in India, was struck, one man being killed and two injured. In this case a spark was actually seen to rise from the floor inside the lighthouse. The man who was killed was standing near a coil of galvanized iron fencing-wire which lay inside the room; this was only five feet from the conductor, though separated from it by the outside wall.

These and other similar events gave people the idea that lightning conductors were of little use, and then it was that Sir Oliver Lodge began to make a special study of the subject.

Clerk Maxwell had already pointed out that there is only one perfect protection against lightning, that being to enclose the chamber in a metallic cage or sheath through which no conductor is allowed to pass without being thoroughly connected to it. But of course this method is too costly for ordinary use, though it might be applied to a powder magazine or dynamite factory.

Sir Oliver pointed out that the danger lies not so much in the opposing charges of electricity in cloud and earth, but in the vast store of energy in the stratum or layer between the two (what is called the dielectric). To dissipate such a volume of energy suddenly by means of a thick rod of copper is not the safest way, for an electric discharge is very likely to overshoot itself and not to be exhausted in a single swing. Sir Oliver says:

> The hastily discharged cloud, at first supposed positive, over-discharges itself and becomes negative; then again discharges and over-discharges till it is positive as at first, and so on with gradually diminishing amplitude of swing, all executed in an extraordinarily minute fraction of a second, but with a vigour and wave-producing energy which are astonishing.

It was usual formerly to use a thick and costly copper rod, copper because it is the best conductor of electricity, but Sir Oliver showed that a thin iron wire may actually be better. Its extra resistance dissipates some of the energy and tends to damp out vibration sooner. A side flash is less likely to occur from thin iron than from stout copper. He proved also that metal tape is electrically better than a round rod, but that four detached and well-separated wires are better than either.

Sir Oliver's experiments have been of very great help to the British Post Office, and to telegraph, telephone, and cable companies, in showing them how to protect their wires and cables from the effects of lightning. Besides proving that iron is better than copper for this purpose, he demonstrated that several points are preferable to a single point, that conductors should be continuous and all unavoidable joints soldered; that *high* lightning rods are not of special value; that greater surface should be given to earth connexions; and that both deep and shallow earths are required. Also he proved that it is most necessary to inspect all lightning rods at regular intervals.

It was his work on lightning conductors that drew Sir Oliver's attention to the investigation of wireless waves, and it may be news to some of our readers that it was he who invented the coherer which made possible the success of Marconi's early experiments in wireless. This is what the great Hertz himself said:

> Professor Oliver Lodge, in Liverpool, investigated the theory of the lightning conductor, and in connexion with this carried out a series of experiments on the discharge of small condensers which led him on to the observation of oscillations and waves in tones. Inasmuch as he entirely accepted Maxwell's views and strove to verify them, there can scarcely be any doubt that if I had not anticipated him he would also have succeeded in obtaining waves in the air and thus also in proving the propagation of electric force.

In other words, it was largely by chance that Sir Oliver did not achieve the honour of being the originator of practical wireless telephony. As it is, he is one of the great living authorities on this subject, and has both written and lectured widely upon it. But Sir Oliver's special subject is ether—perhaps the greatest of all puzzles to the average person without scientific training.

"Many physical phenomena," says *Chambers's Encyclopædia,* "are supposed to be due to the propagation of a state of stress or motion through a medium filling all space. Such a medium is called an ether." Yes, but our difficulty is that ether appeals to none of our senses. It cannot be seen, felt, smelled, tasted, or tested by any chemical process known to man. It has no weight, apparently no substance. How, then, can man appreciate its existence?

Man, indeed, can only appreciate it indirectly. Sir Isaac

Newton said it was impossible to conceive of direct action at a distance, yet light and radiant heat reach us from the sun more than ninety million miles away, while wireless electric waves travel at the same speed as light, and there is no appreciable interval between the striking of a note on a piano in London and its reception by a listener at Edinburgh or Plymouth.

In his book *The Ether of Space* (published by Benn) Sir Oliver Lodge says:

> No form of ordinary matter, solid, liquid, or gaseous, is competent to transmit a thing with the speed of light. For the conveyance of radiation or light all ordinary matter is not only incompetent, but hopelessly and absurdly incompetent. Yet it is transmitted—for it takes time on the journey, travelling at a well-known and definite speed, and it is a quivering or periodic disturbance falling under the general category of wave motion.

Gravity too depends upon the existence of some such medium as ether. The power of gravity is enormous, and of it Sir Oliver says: " The force with which the moon is held in its orbit would be great enough to tear asunder a steel rod four hundred miles thick with a tenacity of thirty tons per square inch."

Sir Oliver continues:

> The question is often asked, " Is ether material ? " . . . Undoubtedly the ether belongs to the material or physical universe, but *it is not ordinary matter.* I should prefer to say that it is not ' matter ' at all. It may be the substance or substratum or material of which matter is composed, but it would be confusing and inconvenient not to be able to discriminate between matter on the one hand and ether on the other. . . .
>
> The essential distinction between matter and ether is that matter *moves* in the sense that it has the property of locomotion and can effect impact and bombardment; while ether is *strained* and has the property of exerting stress and recoil. All

> potential energy exists in ether. It may vibrate and it may rotate, but as regards locomotion it is stationary . . . absolutely stationary, so to speak; our standard of rest.
>
> Now comes the question, how is it possible for matter to be composed of ether? How is it possible for a solid to be made out of a fluid? A solid possesses the properties of rigidity, impenetrability, elasticity, and such like; how can these be imitated by a perfect fluid such as the ether must be?
>
> The answer is they can be imitated by *a fluid in motion.*

Sir Oliver goes on to give examples:

> A wheel of spokes, transparent or permeable when stationary, becomes opaque when revolving, so that a ball thrown against it does not go through, but rebounds. . . . A silk cord hanging from a pulley becomes rigid and viscous when put into rapid motion; and pulses or waves which may be generated on the cord travel along it with a speed equal to its own velocity, so that they appear to stand still. . . . A flexible chain, set spinning, can stand up on end while the motion continues.
>
> A jet of water at sufficient speed can be struck with a hammer and resists being cut with a sword. A spinning disc of paper becomes elastic like flexible metal and can act like a circular saw. . . . In naval construction steel plates are cut by a rapidly revolving disc of soft iron.

We would like to quote further from Sir Oliver's explanation of the nature of ether, but space does not permit, and in any case the reader can turn to the book from which we have given these extracts. We think at any rate that he comes nearer than any other writer to elucidating a subject which perhaps no human brain can completely grasp.

Now it may be interesting to give some short account of the career of this man of many interests and many talents. He was born at Penkhull, near Stoke-upon-Trent, in the year 1851. In 1928, at the age of seventy-seven, he was presented with the freedom of the city of Stoke, and in his speech on that occasion gave some reminiscences of his early days. He went to school at the age of eight, but when only fourteen had to leave in order to help his father, who was head of a prosperous business. He said:

> I used to keep accounts for my father, who traded in lead, clay, cobalt, and other potters' materials. I used every scrap of my time, and was recently looking at an old diary in which I put down every hour that I had wasted. I worked on mathematics and physics. I had a longing for knowledge. I used to work thirteen hours a day when I had a holiday from business. I even worked in trains and tramway cars.

He told a little story of his very early days which shows what sort of boy he was. At the end of the Crimean War a captured Russian gun arrived at Stoke.

> My father placed me by it when they were about to unveil it and told me to stay till he returned. I thought the gun was going to be fired and I stood like the boy on the burning deck. My father went away eating, rejoicing, and speech-making. When he got home late at night my mother said, "Where's the boy? He has not come back." Father replied, "Oh, I forgot all about him." So he ran down and found me still there.

This was good, considering that Sir Oliver could only have been a very small boy at this time.

"I do not suppose I was ever cut out for business," Sir Oliver told his audience. It was hearing Tyndall lecture at the Royal Institution which opened his eyes to this fact and made him realize, with a thrill never since forgotten, that Science was his mistress. Working at odd times and in the evenings, he prepared himself for the Matriculation Examination of London University, and without any help from anybody passed with flying colours. Not content with this very real triumph, he went on to work single-handed for the Intermediate Examination, and this too he passed, gaining first-class honours in physics.

At the age of twenty-one he threw up his business career and entered University College. It was a struggle—a very hard struggle—for he had no money and had to support himself by giving lessons to those better off than himself. The extent of his success is indicated by the fact that within five years he had his degree (Doctor of Science) and was able to marry. Before he was thirty years old he was Professor of Physics at the new University College of Liverpool.

That was in 1881. Six years later he was made a Fellow of the Royal Society, and in the next year received the honorary degree of LL.D. from St Andrews. The famous Scottish university, it may be said, is by no means prodigal of such honours. Since that time Sir Oliver has had similar honours from the universities of Oxford, Cambridge, Glasgow, London, Edinburgh—indeed, from nearly every great seat of learning in his own country and from many abroad as well. In 1900 he was chosen as the first head of the University of Birmingham, and in 1902 received the honour of knighthood at the coronation of King Edward.

In describing an interview with Sir Oliver, in the *Strand Magazine,* Augustus Muir says: " Sir Oliver Lodge has brought Science right to the front door of the ordinary man." This is very true, for Sir Oliver has the uncommon gift of being able to put difficult subjects into simple and understandable language. The millions who have listened to his broadcast talks will all bear witness to this.

Sir Oliver has now retired, and lives at Normanton House, on Salisbury Plain, a charming old place not far from that wonderful relic, the sun temple of Stonehenge. A river flows at the bottom of his garden, and in this garden is a revolving sun parlour where in good weather its owner works. For although he has nominally retired it is not in Sir Oliver's nature to relax altogether; he has written ten books since his seventieth birthday, and he has others in the making.

Yet it must not be supposed that Sir Oliver's life is all work and no play. That may have been so during his early years when it was all that he could do to make ends meet, but later he learned to play golf and croquet. Later still he took up dancing, which, as he rightly says, ' refreshes the machine ' after a day's work and induces sleep. He is keen also on music and on art. The late Lady Lodge was a painter of more than ordinary merit. Sir Oliver's eldest son too is an artist, and also a sculptor, poet, and critic.

Two of his sons, F. B. and Alec Lodge, are known to every motorist as the inventors of the celebrated Lodge plug, while Lionel and Noel Lodge are at the head of the Lodge-Cottrell Company, which does business in Birmingham. They extract large quantities of zinc, tin, and other valuable material from the smoke of furnaces and factories, and the origin of the process which they use is none other than that mentioned at the beginning of this chapter—their father's invention for precipitating fog by electricity.

CHAPTER XII

INVENTION EXTRAORDINARY

The Story of Archibald Montgomery Low

IF Professor Low had not been a scientist and inventor he might have made his fortune as a conjurer, so many are the apparent miracles originating in his fertile brain. As readily he might have written romances like *The Time Machine*, or books such as those of Jules Verne, for none has given more thought to the future.

You may look up Professor Low in a reference book without getting any idea of the many inventions which this remarkable man has to his credit; these inventions number over a hundred, and some are of first-rate importance.

In the reference books we find:

> Professor A. M. Low, A.C.G.L., M.I.A.E., F.C.S., F.R.G.S., F.I.P.L., D.Sc., F.R.A., formerly Honorary Assistant Professor of Physics at Royal Artillery College, Technical Director of the Low Engineering Company, Ltd., Member of Council and Chairman Technical Committee of Institute of Patentees, consulting engineer, and probably the most popular of the professors or doctors connected with the wireless industry. Born in England. Educated at St Paul's School and Central Technical College, South Kensington. Served in the War as Major in the Royal Flying Corps, being Officer Commanding the R.F.C. Experimental Works. He was responsible for the design of wireless torpedo sending gear, the audiometer for photographing sound, the Low two-stroke forced induction engine, and the silencing of the London Underground Railway.

These facts, as usual, give little indication of the romantic story that lies behind them.

Professor A. M. Low's life has been dominated by an interest in physical research, by an interest in motor-cars, and by an incurable habit of inventing things. He has invented all sorts of things, some of them ' queer,' like his special cigarette for motorists—having ash which will not drop off and get into the eyes—or the whistle which he devised for signalling to his dog in a key pitched too high for the human ear to detect it, although its note is heard by the dog as surely as a blare liable to wake up all the neighbours. Such inventions are his hobby.

The cigarette for motorists is typical of these 'brain-waves.' Dr Low noticed that his motoring friends could not smoke when driving a car at high speed, or when a wind was blowing, because the ash from the cigarette entered their eyes. He thought the matter over and at length produced the motorists' cigarette—an ordinary cigarette so treated that while the tobacco is unharmed, the ash solidifies as it burns, with the result that when smoked the whole cigarette can be discarded, with the hardened ash still intact. The Professor has also produced a box for attachment to the dashboard which automatically lights a cigarette each time that one is taken from the container.

Another invention was a pair of garage doors that disturbed the Professor's neighbours by unlocking themselves mysteriously—really in response to a blast on a motor horn. This apparent miracle was made possible by a violin string attached to a delicate mechanism inside the door. As soon as a certain note sounded the violin string vibrated, and this operated an electric switch, which in its turn unlocked and opened the doors. Through this contrivance Professor Low would drive up to his garage, unlock the doors, and enter without leaving his driving seat.

Yet another invention perfected by Dr Low for use in his own home was an early application of the principle of the light-sensitive selenium cell. By shining a light on a certain portion of a door it is possible to unlock and swing open the door, untouched by human hands. The explanation is simple. Inserted in the door was a selenium cell. When under a ray of light its electrical resistance altered, and this change in turn operated a catch and caused the door to swing wide.

Just as baffling to the uninitiated, and more valuable scientifically, was a method of photographing air-cooled engines by invisible heat rays which the Professor developed, thus enabling local overheating of the engine to be discovered while the engine was actually running. Other experiments which he carried out had for their object the increasing in efficiency of artificial light—at present only about 2½ per cent. of the possible light is actually ‘ trapped ’ and used, a striking instance of the embryonic state of our scientific knowledge.

Inventions such as these, however, are little more than the Professor's hobby. His real achievements have been in the fields of scientific research connected with internal combustion (motors), wireless, and sound.

Professor Low was the first man to take a photographic record of sound. This he did by means of an instrument called an audiometer, which records faithfully the strength of every sound coming into contact with the sensitive diaphragm inside it. The diaphragm has a very small mirror attached, reflecting a tiny beam of light on to a strip of photographic paper. The paper is traversed on a slide, and as it moves the beam of light traces an area which is increased or reduced as the sounds are intensified or softened. Silence is registered in a straight line; thus the degree and type of divergence from the line reveals the amount of sound photographed and its characteristics.

This machine was used during experiments carried out a few years ago as part of an attempt to reduce the noise on the London Underground Railways. In a special experimental train it located the three main sources of noise—wheel and rail shock, motor and gear noises, and general loose rattle. These were partly eliminated by filling the hollow roof with asbestos material, by dividing the windows into smaller areas, and by fitting hoods over the wheels, thus deflecting the noise above the level of the ventilating windows.

There was then, as many of our readers will remember, a deafening rattle on the cars, which made conversation practically impossible while the train was in motion, but in the present rolling-stock, embodying the noise-reducing devices, it was found possible to hear the tick of a watch held one foot from the ear. The important change was not in the mere volume of the noise, but in the elimination of its more harmful elements.

Twenty years ago it would have been impossible to reduce noise in this way. For our present ability to track almost any noise to its source we are indebted to Professor Low and his audiometer.

The Professor believes that this problem of noise will attract increasing attention in the near future. Our cities become noisier every year, and an enormous amount of nerve strain is caused by noises that are quite preventable. Professor Low says:

> The future will find noise-reducing devices in use on all traffic, while the same process will be carried into the home and every walk of life. Office windows can be provided with sound deflectors, public buildings and dwelling-places can be 'proofed' to noise.

There is confirmation of this in the new London studios of the British Broadcasting Corporation; although in the heart of London, these are absolutely sound-proof, the audition rooms being ventilated by a method which admits fresh air but no sound. Many London buildings

PROFESSOR A. M. LOW, WITH THE AUDIOMETER WHICH HE INVENTED TO PHOTOGRAPH NOISE have been audiometrically treated, and the process has now spread to aviation, shipbuilding, and the design of talkie theatres. Machinery also can be tested for noisy and wasteful operation.

The achievement with which Professor Low's name will always be associated is the wireless-controlled torpedo; this and not the audiometer provided his greatest thrill.

We have mentioned that as Major Low he commanded the Experimental Works of the Royal Flying Corps during the war. His dream at that time was to perfect a pilotless aeroplane which would be in fact a flying bomb or torpedo, directed by wireless from the ground.

The general opinion, when he spoke of his idea, was that it was fit only for the pages of a novel. But Professor Low had been experimenting for years with wireless and television. For the latter he demonstrated an apparatus before the Institute of Automobile Engineers in 1914. He knew more than his critics about the part which wireless was going to play in their lives within a few years, and, something more difficult to predict at that time, the part which wireless would play in another war if one came.

For two years the Professor toiled to produce an aeroplane that could be controlled entirely by wireless. Like many another inventor, he faced disappointment after disappointment. Often the pressure of other work forced him to abandon the experiments. But always he returned to them. The aeroplane was proving itself the weapon of the future, and Professor Low felt certain that if Britain did not develop an air machine controlled by wireless some other nation would do so, perhaps before the Great War had ended.

At last the Professor produced a machine which he believed would be a success. It was wheeled out of its hangar into the middle of the flying ground. Then the mechanics, after a last examination, left it standing there with engine ticking over.

Professor Low stood before the controls, some distance away. Was it possible for him to control that machine while it was untouched by human hands? "We'll see," he said to the officer standing beside him, and pressed a button. Instantly the engine that drove the wireless torpedo spluttered to full speed, faltered for an instant, and then settled down to a steady hum. Dr Low touched a switch and the machine began to move, gathering speed with every minute, until at length it actually took to the air from its directing rails, being given initial impetus by compressed air, a method adopted years after by the U.S.A. Navy. For some moments the machine flew, directed from that same switchboard on the ground. It was uncanny. Then suddenly, over-elevated, it crumpled up and crashed to the ground. No matter, for the first wireless-controlled torpedo in the world had been successfully launched.

As Professor Low told the authors:

> At that moment I realized that I could succeed in achieving selective wireless control over a flying machine at a distance. Sir Henry Norman, one of the greatest authorities of the day, stated at the time that I had solved the problem of wireless control within the limits of vision. I saw more than that—I saw the possibilities of a manless aeroplane being controlled or located by wireless even if unseen by the human eye.

Discussing that remarkable achievement in the light of more recent developments, Dr Low mentioned that in the successful experiments with wireless control conducted later in the War no power was sent to the torpedo or other machine. That procedure had not been developed sufficiently for use in actual warfare. Wireless control was exercised to influence operative power within the machine controlled. Dr Low said:

> Such apparatus has usually been constructed in two distinct ways. The first is the more or less obvious method of using different wave-lengths to affect different controls of, for example, an aeroplane. The rudder might be turned to the right by sending a radio signal of three hundred metres, or to the left by transmitting a radio signal at two hundred metres wave-length. The disadvantage of this method is that accurate selection by an apparatus which is subject to vibration and travelling at high speed, and which can be 'jammed' by the enemy, is almost impossible to-day.

To overcome this difficulty, various mechanical selectors have been designed. Some are operated by sound, various sensitive strings being stretched to respond to the different rate of vibrations, and these vibration rates being transmitted by wireless, when the trembling string in turn switches on power to the particular control which it is designed to operate.

The most accurate device yet discovered is based upon the running of a motor at the transmitter end of the control and another at the receiver end, at speeds which are carefully synchronized.

This device can be readily understood by first imagining a pencil which is allowed to roll down the side of a sloping table. It will be found that to make this pencil climb up the gradient when it is trying to run down all the time it must be struck upward at a definite rate. If the pencil is pushed down the table by a spring which has a well-defined strength behind it, the rate at which the pencil must be knocked to make it climb will vary according to the natural tension of the spring. This principle has been exploited in a mechanism called a 'pecker.' Wireless signals are sent out from the transmitter to the controlled aeroplane or torpedo at various rates, timed by a clock device, and each of these rates corresponds to the adjustment of the pecker receiving the signals in the controlled mechanism. Contact by wireless is thus obtained, and the action of the pecker in turn controls the aeroplane. By having a row of such instruments in the machine which it is desired to control from a distance, any motion can be secured by transmitting signals at the predetermined rate, and as this rate can be varied every time the machine takes the air—by adjusting the mechanism—interference with the control by enemy hands is not easy. Dr Low says:

> In some of the early experiments it was possible to launch a model aeroplane by means of a compressed air gear, and for the engine to be throttled down in mid-air or for a machine to loop the loop entirely by wireless control. But an almost insuperable difficulty at present is the speed at which controls must be applied, and the difficulty of determining the exact position of the machine when out of sight.
>
> In the far future it may be achieved by radio means, but at present it has been partially solved by allowing the radio control (from a distance) to operate a gyroscope, rather than to set the control itself. By this means water torpedoes have been directed with considerable success, being controlled by a pilot in an aeroplane as far as ten miles away, who sets the course by means of a radio-controlled gyroscope, electrically driven, and mounted in the torpedo itself.
>
> For these machines there is a possible future. They can be used to procure photographic records of countries or areas over which flying with pilots might endanger life. They might serve to operate postal air services flying at great height over prescribed routes, or with slight alteration to record and transmit the actual photographs as taken by a camera carried in the wireless controlled aeroplane, and mechanically worked.

Since the Armistice released him from his Air Force duties Professor Low has followed carefully the various developments in ‘frightfulness,’ such as we may expect will be utilized by armies in the event of the peoples of Europe permitting another war to occur. We mention some of the terrible possibilities which Dr Low's trained vision foresees, because this indication of what another war will mean is the best possible argument for world peace. Professor Low says:

> Cities will be protected against aerial attack in many ways, rays of wireless power being directed at vital parts of the machines from the ground, or from other aeroplanes. Vortex clouds of poison vapour will be released at a sufficient height to render them innocuous to those below, but deadly to the pilots of any machines that entered their zones. Protective rings of radio heat will be used to crumple up invading aeroplanes.
>
> Another new weapon used to disable aircraft will be electrically controlled rockets operated on a strong wire. This will be most useful, for to-day an aeroplane striking the telephone wires is often crashed to the ground.
>
> Poison gas will be introduced in many new and terrible forms, also waves of radio heat; and the equipment of the fighting men and women will need very careful attention by scientific chemists to supply the necessary protection. Deadly germs will also be pressed into service in every possible way to harass both combatants and non-combatants.
>
> The use of the wireless-controlled torpedo at sea, equipped with radio-sighted periscopes, will render necessary travelling 'jamming' stations, which will patrol the coast and send out sufficiently powerful disturbances to paralyse all controls at a distance of several miles.
>
> There will be great activity underground, both for protective purposes and because the introductions of wireless sight and light will mean that night affords no cover. Government and other important centres will be underground; there will be scientifically constructed shelters, comfortably equipped, electrically heated and lighted throughout. Electrically heated suits will be worn during cold weather, enabling the wearers to plug themselves in at different points for shelter. Advanced boring machinery will tunnel underground at high speed, for constructing shelters and trenches.

Summing up this prophecy of future war, which is based upon present developments, Professor Low foresees a dramatic change in the methods both of attack and defence.

> Only recently it was reported from Copenhagen that a Norwegian inventor was bringing forward a defence scheme for Denmark which will dispense with conscripts. The whole defence would be electrical, chemical, and technical, and could be controlled by a small staff of experts. That may be taken as one of the first steps towards the scientific development of attack and defence that must be expected in the future.

Dr Low, however, has not confined his predictions about the future to warfare. Before television had been achieved he was forecasting the day when the business man would be able, by wireless sight and sound, to transact his business from his own home, without coming to a city at all.

He expects the factory of the remote future to be worked by wireless power, transmitted without cables to any part of the country.

Even the problem of how to feed the expanding populations of the world may be solved in the same way, for one of the scientific questions which Professor Low is now investigating is the broadcasting of heat. Already he has succeeded in melting a nail by heat broadcast from a spot two feet away. Can that achievement be repeated over a distance of thousands of miles? If that can be achieved—and, remembering wireless itself, who will say that it cannot?—then perhaps it will be possible to warm the polar regions, and to open up that vast territory for farming and cultivation.

It is a weird dream, but scarcely more strange to us than an aeroplane would have seemed to Julius Cæsar.

Before many decades have passed the dream may have been realized, and herds of cattle be grazing over lands now the home of the polar bear and the blizzard.

One more prediction—a forecast for to-morrow rather than the remote future—is Professor Low's idea as to how the motor-car will develop during the next few years. It should be remembered, by the way, that he is a Vice-President of the Junior Car Club and the Auto-Cycle Union, and that he was awarded the degree of Doctor of Science by an American university for research carried out in connexion with the internal combustion engine and for original investigation into acoustical problems. The Professor believes that we differ from savages only in that we speed up our life and obtain more comfort in order to allow our brains to be less enthralled by our bodies. For that reason he welcomes the prospect of motor-car development outstripping all present ideas on that subject:

> The changes in the bodywork of cars will be great; the prevailing model will be stream-lined, flexible, totally enclosed, with its four or six disc wheels shrouded. The engine of the present, with its dirt, noise, smell, and constant need of attention, wastes over 80 per cent. of the money expended on it; this state of affairs will not be tolerated by the engineer of the future. The heat now given to jacket and exhaust will certainly not all be allowed to go to waste. The engine of the future will most probably be of the injection type or the petrol steam turbine, totally enclosed and certainly not requiring attention more than once a year. The largest touring cars, if of reciprocating type as to engine, will not be of more than 1000 c.c., and the combination of steel and aluminium will be used to a great extent.
>
> Eventually, in centuries to come, power for propelling mechanical vehicles may be picked up from cables laid under all the main roads and tapped through a meter as required. This system will perhaps give way to beam-wireless or inductive power tapped from the air at any time or place. This will reduce the engine space required very considerably, all power being broadcast continually from several stations. Even aeroplanes might be operated by this means.

That prophecy and those that preceded it in this chapter come from the imagination of the man whose genius lifted the first wireless-controlled and pilotless aeroplane into the air. Remarkable as they appear to us to-day, these prophecies touch only the fringe of the almost limitless possibilities of the sciences by which we are solving the secrets of Nature and bringing her boundless resources to the service of the human race.

CHAPTER XIII

THE MARVELS OF MARCONI

The Beginnings of Wireless

FEW scientists have ever had a better start in their life-work than Guglielmo Marconi, but a start is nothing unless the starter makes good use of it, and no man alive has worked harder than this brilliant Irish-Italian, or better deserved the great success and reputation which he has gained.

It is often said that Marconi was not the originator of wireless telephony and telegraphy, and this is true in a measure, for others before him had succeeded in causing electric signals to travel through space from one set of wires to another. Marconi, however, was the first to use the Hertzian waves for this purpose, and to put wireless communication on a practical basis. Very rightly, therefore, his name will go down to future generations as that of the father of wireless.

Years ago Miss Annie Jameson, daughter of John Jameson, the well-known Dublin whisky-distiller, went to Italy to complete her musical studies; there she met and married Giuseppe Marconi, a young Italian of good family. Their eldest son, Guglielmo, was born at Bologna on April 25th, 1874. The boy soon proved that he had brains beyond the average, and while still quite a youngster began to take a keen interest in chemistry.

His mother was a clever woman herself; she encouraged him, and got all the books that she thought would help him. She engaged a tutor for him, and even had built a small laboratory where he could do his experiments.

When Guglielmo was old enough he went to school at

Leghorn, and from that school entered the ancient and famous University of Bologna. Here he came under Professor Righi, famous as the inventor of the Righi oscillator, and turned all his attention to electricity. When only sixteen he had already become interested in the possibilities of wireless communication, and had begun to read all he could find on the subject. He knew that, as long ago as 1854, the brilliant Scot Lindsay had succeeded in sending signals across the river Tay without wires, and that in 1882 Sir William Preece had bridged the Solent by induction.

Young Marconi began experimenting on his father's estate. It is said that his first aerial was supported on two broomsticks and that the signals only travelled a few inches, but he plodded on with his work. The inches became yards, and before long he was able to span a distance of two miles.

Marconi's friends say that he has little of the volatile nature of the Italian, but a cool, deliberate character more resembling that of the Englishman, and a tremendous power of concentration. It is certain that no difficulties daunt him. By degrees he proved that the electric waves which he generated would travel through space for long distances and that they were not affected by hills, buildings, or other natural obstacles. He had triumphed by the time that he was twenty-two, an age at which most young men are only beginning their careers. In 1896 he took out his first patent for wireless telegraphy. Of course a dozen people challenged it, but young Marconi went calmly on his way. He left for England, and proceeded to prove that he 'had the goods.' Before British postal officials he sent messages across the Bristol Channel.

That was in 1897, and by 1899 Marconi was able to communicate between Alum Bay in the Isle of Wight and the sand-banks three miles beyond Bournemouth.

It is interesting to know that the first person to send a paid commercial message by wireless was that great scientist the late Lord Kelvin.

By this time the commercial world was beginning to take notice of this new method of communication. Marconi having proved that he could send messages across the sea from Wimereux to Dover, a distance of thirty-two miles, the British Admiralty took up his system and was shown that the range could be extended to one hundred miles. Marconi himself boldly stated that he would soon be able to send his signals across the Atlantic Ocean, and in 1900 a site was chosen at Poldhu, in Cornwall, tall wireless masts were erected, and with the help of Professor J. A. Fleming a great wireless installation was built.

Before we describe Marconi's first efforts to bridge the Atlantic we must mention the first big advertisement which wireless communication obtained. In 1900 a few of the steamship companies were already beginning to instal wireless in their vessels, and one ship so equipped was the Royal Belgian steamer *Princess Clementine.* On January 1st, 1901, this steamship saw the barque *Medora*, of Stockholm, hard and fast on the Ratel Bank, and being herself unable to help sent a wireless message to La Panne, on the Belgian coast. La Panne communicated with Ostend, and within an hour a tug was on its way; it succeeded in saving the *Medora* from her perilous position. A very few hours' delay, and the *Medora* would have been a hopeless wreck.

The new Poldhu station was fitted with twenty masts, each two hundred and ten feet high, and the current of electricity was powerful enough to operate three hundred incandescent lamps. The wave thus generated had a length of about a fifth of a mile, and the rate of vibration was roughly eight hundred thousand to the second. Marconi believed that with this power he could bridge the whole width of the Atlantic Ocean, but many experts said that this was impossible, because his waves would fly out into space. Marconi was untroubled. He sailed for America, and on December 6th, 1901, landed at St John's, Newfoundland, in company with two assistants, Kemp and Paget. It must be remembered that there was no receiving station in Newfoundland. Marconi had to improvise one; he set up his instruments in the old barracks on Signal Hill.

On December 10th he sent up a box kite, a huge thing nine feet high, which was intended to carry the aerial, but the wind was so strong that it snapped the wire and carried the kite miles away out to sea. Marconi next tried a small balloon filled with hydrogen. Again he had no luck, for, like the kite, this broke away and the wire fell to the ground. Marconi rigged up another kite, and on Thursday, December 12th, this was sent up. The wind was still strong—so strong that it took the combined strength of all three men to moor the kite securely. But at last this was done, and it strained in the gale at a height of about four hundred feet.

Before leaving England Marconi had arranged with his people at Poldhu for them to send a certain signal at a fixed time each day. This was to be the Morse letter S, represented by three dots. They were to begin at three o'clock English time—that is, about eleven-thirty Newfoundland time—and to go on for three hours. At noon on that eventful Thursday Marconi sat in the low-roofed room in the barracks with a telephone receiver on his head. A wire ran out of the window to a pole, thence upward to the kite which was plunging in the cold wind. At the bottom of the cliff, some three hundred feet below, the great Atlantic surges roared. For nearly half an hour nothing happened; then a slight click reached the ears of Kemp as the tapper struck against the coherer. Kemp stood breathless, but Marconi's face showed no sign of excitement. Presently Marconi took off the receiver and handed it to Kemp.

" See if you can hear anything," he said. Kemp fitted it over his own ears, and a moment later, faint, yet quite distinct, came three little clicks, the letter S as agreed. A little later they came again, so clearly and continuously that neither Marconi nor Kemp had any doubt that the experiment had succeeded.

Even then Marconi would not give his news to the world. He waited until he had received fresh signals on the following day; then on Saturday word was flashed all over the world announcing that for the first time in history messages had been sent by wireless from England to America.

And was Marconi believed? Not a bit of it. One Press correspondent received from his principals a cablegram saying, " Your message about Marconi simply incredible. Please be extremely careful what you wire." Columns were written in the newspapers proving to the satisfaction of their writers that Marconi had been deceiving himself—that all he had heard were atmospherics—that it was flatly impossible to wireless over such a distance as two thousand miles. The few who did believe were those who knew Marconi. Of these was Sir William Preece. Marconi was far too big a man to be worried by the nonsense that was written and printed, but he resolved quietly to give these doubters a proof which even their sceptical brains could not withstand. He came back to England, rigged up a receiver aboard the big liner *Philadelphia*, and took passage on this ship for America.

Before sailing from Cherbourg he gave instructions to his engineers at Poldhu to send out signals at certain definite intervals. Their time was kept at Greenwich standard, and on the ship they had watches set to the same standard so that they would know to a second when to expect the signals.

Marconi and his party had four staterooms on the upper deck, and in one of these the instrument was installed. For sending purposes this instrument was not capable of more than one hundred and fifty miles, and it was announced that no commercial messages would be received or sent. Four aerial wires running to the head of the mast were used for reception, and one wire was passed over the side of the vessel, establishing an earth. At Poldhu dynamos created an energy of twenty thousand volts, and this high tension was transformed up to two hundred and fifty thousand by means of condensers. When the operator pressed the key a spark a foot long and as thick as a man's wrist sprang across the gap. It was the most powerful electric flash which man had ever produced.

The *Philadelphia* left Cherbourg just before midnight on Saturday, and messages were received and sent until the one hundred and fifty mile limit was passed. Very much passed, indeed, for the ship was two hundred and fifty miles from Poldhu when the last message was received by the land station. On Monday morning Chief Officer Marsden was in the cabin when a message was ticked out: "All in order. Do you understand?" The ship was then fully five hundred miles from Poldhu, and Marsden, full of excitement, ran out to tell his fellow officers of the feat. They laughed.

"Do you expect us to believe that?" they jeered.

"All right," smiled Marsden. "Just wait till to-morrow." Next morning the officers crowded in the operating cabin, where Marconi sat, watch in hand. He opened a brake on a coil of tape and the white strip began to unroll.

"Here it comes," said Marconi calmly, and tap-tap-tap began the inker, recording messages sent out from a source nearly one thousand miles away.

The days following were full of excitement for every one but Marconi, who seemed quite cool. At midnight on the Tuesday the signals came clearly as ever, and on Wednesday, when the ship was one thousand five hundred and fifty-one miles from Poldhu, there came the message again: "All in order. Do you understand?"

To make a long story short, messages were received at a distance of two thousand and ninety-nine miles, and before witnesses whose word could not be doubted. The Newfoundland record had been broken, and Marconi reached America tired from lack of sleep, but triumphant.

Now for the first time in all his years of work Marconi permitted himself to prophesy. "Give me," he said, "a week at Nantucket, and I will guarantee to receive signals from England. We shall be able to transmit and receive any and all kinds of messages across the Atlantic."

The world doubted no longer, and Marconi's triumph was assured. The Italian Government put a warship at his disposal, and that summer he cruised in the Baltic and the Mediterranean, sending messages over distances up to fifteen hundred miles and proving that great mountain ranges such as the Alps and Apennines had no effect in blocking his signals. In the autumn he went back to Newfoundland, where he set up the wireless station at Glace Bay. Before the year was out messages were flying to and fro across the Atlantic.

The very first message from Newfoundland conveyed the "respectful homage" of Marconi himself to King Edward VII, and instantly there came back congratulations from his Majesty on "the successful issue of your endeavours." "The King," continued the message, "has been much interested in your experiments, as he remembers that the initial ones were commenced from the Royal yacht *Osborne* in 1898." This refers to the fact that while the King (then Prince of Wales) lay ill aboard the *Osborne* no fewer than one hundred and fifty messages were sent from the yacht by wireless—chiefly private communications between Queen Victoria and the Prince.

Marconi's success in bridging the Atlantic encouraged him to greater efforts. Soon he discovered what is called the persistent wave method of wirelessing, which produces trains of undamped or slightly damped waves of high frequency. This enabled him to dispense with the immensely powerful spark which he used in his earlier system. While conducting his earlier experiments Marconi, like every one else, was under the impression that great distances could not be covered without the use of very high masts and great lengths of suspended wires. The idea was that the waves were hindered by the curvature of the earth, but Marconi's Newfoundland experiments proved that this was not the case and that the waves curved with the earth's surface. Marconi's faith in his invention was boundless, and in 1902 he foresaw already that within a few years liners and warships would be in constant communication with the land.

As we have already mentioned, passenger-carrying ships were beginning to instal wireless as early as the year 1900, and before long things began to happen which proved the enormous value of the new invention. We have spoken of the rescue of the *Medora* through the use of wireless. A little later the captain of a big liner on its way to America became aware that he had aboard a gang of card-sharpers who were swindling passengers. As he approached New York he sent a wireless message to the authorities. Detectives came out by tug and met the ship, the members of the gang were recognized, and to their intense disgust found themselves arrested and presently sentenced to long terms of imprisonment.

It was not until 1909, however, that the value of wireless as a life-saver was fully proved. In January 1909 the White Star liner *Republic* was rammed in mid-ocean by another vessel, the *Florida*. There was thick fog at the

THE MARCHESE MARCONI SPEAKING FROM HIS YACHT IN GENOA HARBOUR TO AN AUDIENCE IN SYDNEY

time. The collision was so violent that the roof and one wall of the *Republic's* wireless cabin were ripped away, while the shock put the dynamo out of order and plunged the whole place into darkness. The captain, who realized how badly his ship was holed, sent a message to the wireless operator asking him, if possible, to call for help. The wireless operator, a smart young fellow named Jack Binns, set to work at once. With the ship slowly sinking under him, he managed somehow to rig up an apparatus which would dispatch messages, and, having done so, sat down with the telephone receiver on his head and a blanket around his shoulders and began sending out the C.Q.D., which in those days was the call for help.

An answer came, and presently he was able to send word that the great *Baltic* was racing to the assistance of the threatened ship. Three other ships heard, but all were too far away to arrive in time.

Water was pouring into the holds of the *Republic*. The *Florida* was standing by, and though badly injured herself she had more chance of floating than the *Republic*, so the whole of the *Republic's* passengers and crew were taken aboard her. For ten hours on end young Binns went on sending out his appeal; then the batteries which he had been using in place of the wrecked dynamo gave out. But he had done his work. Up came the *Baltic* and took off no fewer than one thousand two hundred and forty-two passengers from the crowded *Florida*; then she took the *Republic* in tow. It was too late, however, to save the *Republic*, which shortly sank. Yet not a life was lost, and every newspaper in the world was full of the story.

We do not know whether there has ever been made any close calculation of the number of lives saved from shipwreck through the use of wireless, but we are safe in saying that no single invention has ever been the means of saving a greater number, and every year that passes sees that number increased.

But the saving of lives is only one of the many benefits which wireless communication has conferred upon the world. Wireless in the home has become such a commonplace that very young folk hardly realize that it is only a short time since there was no such thing. Wireless is invaluable in the work that it is doing for the education and entertainment of young and old. Its social value from another standpoint was proved in Britain during the great strike of 1926, when there were no newspapers, and when it served to tranquillize the public mind.

Wireless is perhaps of greatest value in drawing the various nations of the world closer together. An English boy who can listen to a French orchestra playing or to a German singing is brought close to the people of other countries. Possibly he gets an idea of them quite different from that which his father had when he was a boy twenty or thirty years ago. He does not want to fight them. Wireless is becoming the handmaid of the League of Nations in the prevention of war.

Wireless telephony is already so perfect that speech is possible between any two points on our planet, however far apart. Quite recently an aeroplane circling above the everlasting ice of the Antarctic continent was in communication with a station in the northern part of the United States. Yet Marconi's own belief is that the science is still in its infancy, and that it is by no means impossible that through wireless we may eventually get into touch with other worlds. Since 1920 wireless operators have been puzzled by interruptions to their signals. Operators have heard these signals simultaneously in London and New York, and Marconi himself has said of them:

> We occasionally get very queer sounds and indications which might have come from somewhere outside the earth. We have also noticed that in these interruptions some letters occur with much greater frequency than others. The letter S

> is one of these. . . . As yet we have not the slightest proof as to the origin of these interruptions. They might conceivably be due to some natural disturbance at a great distance, such as eruptions on the sun.

Asked whether they might not possibly be caused by attempts on the part of some other planet to communicate with the earth, Marconi said: "I do not rule out that possibility."

Before we end this chapter we must say a word about Marconi the man. He stands about five feet ten inches, is slim and well built, and very erect. His head is large and well shaped, with a high forehead. His manner is quiet and deliberate, he has none of the emotional fervour of the Italian, and the only evidence of his Irish blood is the genial smile which now and then brightens his face. He is intensely energetic and has an amazing power of concentration. He is popular with his assistants because of his fair-mindedness, but he is not what Americans call a 'good mixer.' He is very fond of music. The keenest of his senses is that of hearing. Trained by long years of listening to small vibrations in a telephone receiver, his ears are far more acute than those of most of his fellow-men. He has great patience, and believes that there is hardly any problem which cannot be solved by hard work. He is keenly interested in all aspects of human invention, and declares that the real Golden Age of discovery is only now beginning to dawn upon the world.

CHAPTER XIV

THE BIRTH OF ELEMENTS

Dr R. A. Millikan Discovers how Matter is Created

IF you look at your face in a looking-glass the image which you see is not quite so distinct as the face itself, this being due to the fact that some of the so-called radiant energy has been transformed by the reflecting glass and converted into heat. If you strike a tuning fork the vibrations die down, partly because they are communicated to the surrounding air, partly because of the production of heat in the metal of the fork itself. If you strike a nail with a hammer only a part of the energy of your blow is employed in driving the nail into the wood, the rest is dissipated in heat.

All forms of energy tend to take the form of heat, and this heat drifts out into the ocean of atmosphere and the abysses of space, and is apparently lost for any useful purpose. Small wonder, then, that the scientists of the nineteenth century came to the conclusion that the universe was like a clock which, after being in some mysterious manner wound up, was running down, and was destined at last to reach a state of equilibrium equivalent to death. Everything dies, they said, and suns and worlds are no exception to the rule.

With the twentieth century came new discoveries. The Curies isolated radium, as told in another chapter; Sir Ernest Rutherford proved that each atom is probably a miniature solar system, with a central sun around which tiny satellites are whirling. The theory of radio-activity was investigated, and it was discovered that radio-active elements were slowly dissipated through their electrons being flung off into space. Yet nothing was found to upset the belief that our solar system, presumably like all other solar systems, was doomed to eventual dissolution. The discoveries made only tended to give a clearer idea of the ways in which energy was dissipated. The matter was put in a nutshell by that brilliant writer and scientist Professor Jeans, who wrote:

> Mass is converted into radiant energy, but that process is nowhere reversible. Matter will thus ultimately be all converted into radiation—*i.e.*, it will simply disappear. . . . Thus observation and theory agree that the universe is melting away into radiation. Our position is that of polar bears on an ice-berg that has broken loose from its ice-pack surrounding the pole and is inexorably melting away as the ice-berg drifts to warmer latitudes and ultimate extinction.

Then came a glimpse of something new. In 1903 M'Lennan and Rutherford discovered certain radiations near the earth's surface so penetrating that they were capable of passing through thick screens of lead. Professor Jean Perrin, who holds the chair of physico-chemistry at the University of Paris, was greatly interested, but unable to decide upon the source or nature of these rays.

In 1910 the Swiss scientist Göckel went up in a balloon to a height of more than three miles, taking with him an enclosed electroscope (the instrument used for measuring electric discharges), and what he found was that at this height the radiation was stronger—far stronger than nearer the earth. So its source, it seemed, was somewhere outside the atmosphere of this planet. Hess, in Austria, and Kolhörster, a well-known German scientist, made similar experiments.

The latter sent up an electroscope to the great height of nearly six miles, and found that the power of these new rays was actually seven times greater there than on the ground. After further investigations he announced his belief that the rays emanated from certain groups of stars at vast distances from our system.

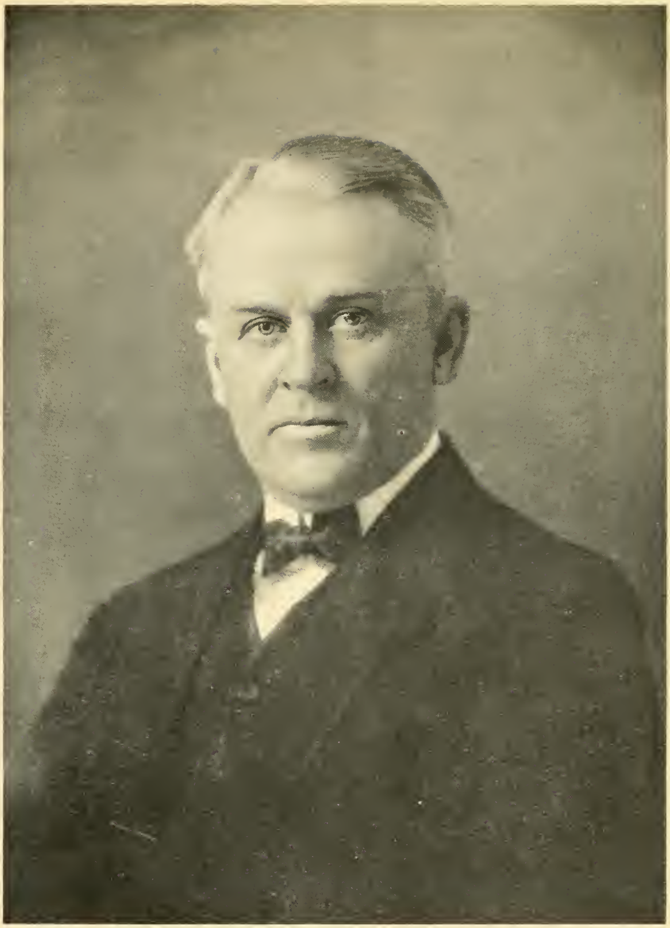
The War intervened, and it was not until the end of 1921 that Dr R. A. Millikan began to investigate these ‘ cosmic ’ rays.

Working with another scientist named Bowen, he sent up electroscopes to a height of nearly ten miles. Of course Millikan did not go up himself, for in the bitter cold and rarefied air of such a height no warm-blooded creature such as man could live. He used what the meteorologist calls a *ballon sondé*, a small pilot balloon, to lift his instruments. The results of these experiments corresponded well with those obtained in Europe before the War, but the source of the rays was still as obscure as ever. Though it seemed fairly certain that their source was somewhere in space, it did not appear probable that they came from any special group of stars. One thing became very certain. The newly discovered rays had nothing to do with the sun, for they were just as powerful at midnight as at midday.

The next step was in the summer of 1923, when Millikan and Otis took electroscopes to the top of the lofty American mountain known as Pike's Peak. These electroscopes were shielded with heavy lead screens. At the same time Kolhörster was working on Alpine glaciers, measuring how far the rays would penetrate ice. Both investigations revealed that the rays were astonishingly ‘ hard ’ —that is, had very great penetrative power—but the mystery of their origin remained.

Many scientists of repute had no belief in these cosmic rays. In 1925 Hoffman, the well-known German scientist, declared his belief that the rays were not of cosmic origin, while in America Swann was of the same opinion.

Outside the world of Science few people had even heard of these strange rays or knew about the arguments for and against their origin, but Millikan, who now had Dr



DR R. A. MILLIKAN

Cameron to help him, continued his researches. He began a series of new experiments by climbing mountains and sinking electroscopes in deep, clear lakes at great heights. The first lake visited was Lake Muir, which lies at a height of eleven thousand eight hundred feet, and here the sealed electroscope was sunk to a depth of no less than sixty feet before all signs of ionization (disturbance by rays) ceased.

Dr Millikan says:

> This was the first time the zero of an electroscope—the reading with all external radiations, both local and cosmic, completely cut out—had been definitely determined, and the results accordingly began to show that it was possible to make with certainty determinations of the absolute amount of the penetrating radiation.

It must be explained that most water is radio-active, and therefore affects the electroscope. From Dr Millikan's point of view, the beauty of these deep, snow-fed lakes is that their water has hardly any radio-activity, actually less than one-hundredth of that of ordinary tap water.

Next, readings were taken in another snow-fed lake three hundred miles to the south, at a height of six thousand seven hundred feet, and the readings of the electroscope were found to have a *similar curve*, but with each reading displaced just six feet upward. But six feet of water is exactly equal, in absorbing power, to a layer of atmosphere five thousand one hundred feet thick—in other words, to the difference in the height of the two lakes. Here then was proof of three things:

1. That the effects in Lake Muir had not been due to any radio-activity in the water.

2. That the source of the rays affecting the electroscope was not in the layer of atmosphere between the two altitudes.

3. That in two different places, three hundred miles apart, the rays were exactly alike at the same heights.

Still Dr Millikan was not content. There is no one more thorough in his methods than the modern scientist. In 1926 fresh experiments were carried out in Lake Miguilla, in Bolivia, a lonely tarn lying at a height greater than that of the summit of Mont Blanc—that is, more than fifteen thousand feet.

Professor C. T. R. Wilson had suggested that the rays might be caused by the impact of electrons endowed with many millions of volts of energy acquired in thunderstorms. But such a lake as Miguilla is completely screened from such effects, and the experiments there definitely discredited Professor Wilson's theory. What is more, the readings of the sunken electroscope gave results similar to those achieved in North American lakes, thus proving that the rays had equal power in both hemispheres of our planet.

In 1926 Dr Millikan and his assistants constructed electroscopes more delicate than any that had yet been made, and in the following year used these in two lofty Californian lakes named Gem and Arrowhead. With these electroscopes zero was not reached until the instrument had been sunk to a depth of one hundred and sixty-four feet, showing that the sensibility of the instrument had been increased *eightfold*. Taking into account the absorption of the rays by the atmosphere above Gem Lake, the new experiments revealed rays *so penetrating as to pass through two hundred feet of water or eighteen feet of lead before being completely absorbed.*

And now no doubt our readers will be wondering whether these so-called ' cosmic ' rays have any significance for the man in the street, or any special importance in the working of the universe.

The answer can best be given by Dr Millikan himself. Speaking in 1928 before the California Institute of

Technology, he said, " My recent experiments with cosmic rays leave no doubt in my mind that the process of creation is now going on in the heavens, and that our earth is not, as has long been believed, a disintegrating planet." He went on to say that the extraordinarily penetrating qualities of the cosmic rays provide not only the first direct evidence that the more abundant elements are now in process of being created out of positive and negative electrons, but also the first indication as to the general character of the specific act or acts by which the atom-building process goes on.

In his book *Science and the New Civilization* (Charles Scribner's Sons, 1930) Dr Millikan says:

> These rays are not produced, as are X-rays, by the impact upon the atoms of matter of electrons that have acquired large velocities by falling through powerful electrical fields . . . but they are rather produced by definite and constantly recurring atomic transformations involving very much greater energy changes than any occurring in radio-active processes.

Where these changes take place Dr Millikan does not profess to know definitely. He speaks of them as happening in some " infinitely remote abysses of inter-stellar or inter-galactic space where the pressures and temperatures are close to absolute zero." But he has come to the definite conclusion that the rays which he has trapped and measured with such extreme accuracy are, in his own picturesque phrase, the ' birth-squeaks ' of elements such as helium, oxygen, silicon, and iron.

Atom-destruction is constantly going on. At the centre of great suns, where the temperature may exceed thirty million degrees, atoms as we know them cannot exist. Our own sun is constantly flinging forth electrons which are the remains of broken atoms, yet side by side with this process there is one of construction.

The universe, in fact, is being wound up as fast as it runs down. This is the extraordinarily interesting conclusion to which Dr Millikan's researches have led him. They have led him even farther. They have strengthened his conviction that there is something much greater than ' mechanism ' behind the universe. To quote again from his writings:

> Science is sometimes charged with inducing a materialistic philosophy. But . . . the physicist has had the bottom knocked out of his generalizations so completely that he has learned with Job the folly of " multiplying words without knowledge," as did all who once asserted that the universe was to be interpreted in terms of hard, sound, soulless atoms and their motions. . . . The mechanistic is bankrupt.

In brief, Dr Millikan believes that Science will strengthen faith in an unseen power, and not run counter to the religious impulse of the human spirit.

CHAPTER XV

THE MAN WHO SPEEDED UP TRAVEL BY SEA

Sir Charles Parsons and the Turbine

THE first man who ever described the surface of the moon was the third Lord Rosse, famous as the builder of the first really large telescope. It weighed twelve tons and was mounted in the park at Parsonstown at a cost of no less than thirty thousand pounds. That was more than eighty years ago.

Lord Rosse was much more than an astronomer. In 1854, when the Crimean War was raging, he proposed that the British Admiralty should build ironclad ships. He suggested a steamer of about fifteen hundred tons, covered with four inches of iron. This vessel was to have no bulwarks and no funnel, and her sides were to be only fourteen inches above the water. Such a ship, he said, could sink an opponent with one blow of her cutwater. In fact, he planned a monitor years before the first of such vessels was actually built.

The children of such a man had every chance to learn engineering; one of them at least, the youngest son and the subject of this chapter, has become world-famous as the inventor of the Parsons steam turbine. When he was only ten years old Charles Parsons was already making small working models of cars and boats. He even made a submarine. A little later, in his father's workshop, he constructed an air-gun. Not a toy, for he says that he well remembers his delight at shooting a rabbit with it.

His next effort was a sounding-machine. This consisted of a glass tube closed at the bottom and with a cork at the top. A tiny hole no wider than a hair was made in the glass, and the depth of water was recorded by the amount of water that entered the tube through this tiny aperture. Though still a boy of twelve, Charles Parsons had actually anticipated the principle of the sounding-machine afterward constructed by the famous Lord Kelvin. Sir Robert Ball, the great astronomer, was a friend of Lord Rosse, and when he cruised with the family on their yacht helped the boy inventor to make soundings with this machine.

Later, Charles Parsons went to Cambridge, where the engineering school was just starting under Professor James Stewart. Charles Parsons was one of Stewart's first six students, and when he left Cambridge in 1876 was Eleventh Wrangler. He was also a first-class rowing man, for he had won his college pair of oars. Then he went to Armstrong's, at Elswick, where he served his apprenticeship, and from there went to Kitson's, at Leeds, in whose shops he began to work on high-speed steam engines.

It was in the eighties of the last century that competition for the Atlantic record had become fast and furious. The Inman and White Star Lines had been striving with one another for years, then the Guion Line struck in, and in 1879 their *Arizona* crossed the Atlantic in seven days ten hours and a few minutes. Three years later the *Alaska* of the same line beat this record by four hours, and in June 1884 the National liner *America* was the first vessel to cross in under seven days, only to be beaten a few weeks later by the *Oregon*, afterward mysteriously sunk off Fire Island.

Then the Cunard bestirred itself and built the *Etruria* and *Umbria*, each of about eight thousand tons and eighteen knots speed. The writer, crossing the Atlantic in 1886, in the old National liner *Egypt*, saw the *Umbria* coming up astern and watched her pass and race away toward the horizon. Both these ships were able to do the journey in a little over six days, but they were beaten by the Inman *City of Paris,* the first to break the six days record. There followed the *Teutonic,* and after her came the new Cunarders *Campania* and *Lucania,* each of thirteen thousand tons, and able to do the voyage in less than six days.

In 1887 a torpedo-boat called *Ariete* was built for the Spanish Navy; this boat attained the then unheard-of speed of twenty-six knots. In 1893 this speed was beaten by the *Daring,* a British boat which notched twenty-eight knots. In 1896 another British vessel, H.M.S. *Desperate,* was the first to reach thirty knots, and in 1899 H.M.S. *Albatross,* constructed of a new tensile steel, reached thirty-two knots.

This was about the limit for the old-fashioned reciprocating engine, and it was not much fun to drive these craft at full speed. The vibration was terrific, and the decks were swept by a storm of red-hot dust from the funnels. Both weight and strength were sacrificed for the sake of speed, and Admiralty engineers realized that these vessels were useless for sea-going service except under the most favourable conditions. So a halt was called in the race for speed.

Charles Parsons was one of those who realized that a new form of marine engine must be devised. He turned his attention to the form known as the turbine. He did not invent the turbine, which is actually the oldest form of steam engine known, for Hero of Alexandria, who lived one hundred and fifty years before Christ, built a toy-like turbine in which a wheel was driven round by a jet of steam. In 1577 a German mechanic constructed a similar machine, which he used for the humble purpose of turning a joint on a spit. In 1784 Watt worked for some time on a small steam turbine, and in 1815 the famous Cornish mechanic Trevithick made similar experiments.

All through the nineteenth century inventors experimented with the turbine, but none of them got far with it. All could drive wheels with steam jets, but the waste of steam was so great that the work done by the steam could not compare with that done by the reciprocating engine. The turbine got a bad name as a 'steam-eater,' and the general opinion among engineers was that it would never be of any practical value. One of the few men who held the opposite opinion was the great Lord Kelvin.

But Charles Parsons was something more than an inventor; he was a scientist and understood the laws of thermo-dynamics (power produced by heat). He realized the possibilities of the turbine and set himself patiently to work to overcome its difficulties and disadvantages.

The reciprocating engine is one in which steam-pressure propels a piston connected with a crank by means of which the to-and-fro movements are converted into rotary action. In the turbine this action is obtained by making steam drive direct upon vanes or blades attached to the rotary parts, so that the steam does its work in a much more simple and direct manner. The chief contrast between the two forms of engine is that in the reciprocating engine the steam has a velocity of less than one hundred feet per second, while in the turbine it attains the tremendous velocity of two thousand to three thousand feet a second.

There are several reasons why the reciprocating engine can never make use of anything like the full power of steam. One is the alternate heating and cooling of the cylinder walls; another is the friction due to the large number of rubbing surfaces; a third is that momentum and inertia must be overcome at every stroke of the piston; and a fourth the fact that if superheated steam is used the oil for internal lubrication carbonizes.

The advantages of the turbine are that the motion is continuous, there is no vibration, no need for internal

SIR CHARLES PARSONS

Photo by Russell, London

lubrication, and that the steam strikes on each part of the engine at a constant temperature. Its disadvantage is that unless the highest possible number of revolutions is attained there is a leakage of steam, which therefore fails to yield up the whole of its energy.

Charles Parsons constructed his first turbine in 1884–85 at the works of Messrs Clarke, Chapman, Parsons and Co., at Gateshead, and this original machine is to-day in the South Kensington Museum. It was of what is called the ‘ parallel flow ’ type, and in the patent which covers it it is stated that the steam operates in successive stages, " undergoing expansion, and falling in pressure in each, until it leaves the last at a velocity not greatly above that which is practically attainable by the motor itself."

In this machine the rotor was built up of rings of gun-metal strung on a central shaft. The blades were cut at an angle of about forty-five degrees out of the solid metal on the edges of the rings, yet even as early as this the inventor hinted that " in some cases it may be convenient to make the blades of sheet metal and to secure them in suitable grooves or recesses in the rings," and that " other forms of blades may be employed." At a later date it was found that curved blades were much more efficient.

This small turbine was coupled to an electric generator and used for experimental work. The first trouble was that the pedestals heated, causing the blades to foul the casing, but this was soon overcome. The next problem was to find the right form of blade. In 1888 curved blades were used and were found to be a great improvement.

The first Parsons turbine to be put into commercial use was built for the Cambridge Electrical Power Station in the year 1892. Professor—afterward Sir Alfred—Ewing was deputed to test this engine. He came full of doubts, but remained to bless.

" It was," as Sir Charles said recently, " a red-letter day for the turbine when it beat the reciprocating engine in economy of steam and justified the proposal to apply the turbine to main propulsion."

Then began work on the first turbine-driven ship. Models about two feet long were made, and towed by means of a fishing-rod in a small pond at Ryton-on-Tyne, and afterward a six-foot model was made which was driven by a powerful twisted rubber spring. The working speed of the propeller was no less than eight thousand revolutions a minute.

This model was so satisfactory that the ship herself was built. *Turbinia*, as she was called, was a tiny vessel, one hundred feet long, nine feet beam, and with only three feet draught, giving a displacement of forty-four tons. Small indeed to hold an engine giving two thousand horse-power.

Her first trial was made in November 1894, and was very disappointing. The propeller was a two-bladed screw of thirty inches diameter. It was driven at the tremendous speed of the turbine (for in those days, remember, there was no gearing down), and the result was excessive 'slip.' In other words, the screw spinning at such furious speed (one thousand seven hundred and thirty revolutions a minute) made a hole in the water behind it, and caused what is called 'cavitation.' The loss by slip, or loss of grip on the water, was very nearly half the total power.

A single four-bladed propeller next tried was equally unsatisfactory, and Parsons then built multiple propellers, three small screws on each of two shafts. By this means slip was reduced to thirty-seven per cent. and a speed of nearly twenty knots was reached, yet even this was not satisfactory. There is not space here to describe all the long, patient, and costly experiments which were carried out before the problem was solved. Photographs of 'cavitation' were taken by means of an arc lamp. With a propeller running at fifteen hundred revolutions a minute in hot water the cavities about the blade could be plainly photographed.

New engines were fitted, and three shafts were used with three small propellers on each. At last the little boat began to move. She did more than thirty-two knots, and the experts became greatly interested.

1897 was the year of Queen Victoria's Diamond Jubilee, and the greatest Naval Review in history was held at Spithead. Into the array of vast steel-clad giants slipped the tiny *Turbinia*, travelling at a speed of thirty-five knots, or forty miles an hour. The newspapers were full of accounts of " The Fastest Vessel Afloat." One correspondent wrote:

> *Turbinia* is propelled by an engine different from any that was put before into a boat. It has no fly wheel, no backwards and forwards movement of rods and pistons, no intricate valves; it is a hundred times simpler than the ordinary steam engine and as easy to understand as a windmill. Indeed it is quite like a windmill in this, that the steam, being driven against the fans of specially made wheels on the three propeller shafts, makes these turn very rapidly, and of course the screws turn with the shafts. . . . The screws of *Turbinia* make about two thousand five hundred revolutions a minute without any vibration, whereas the best marine engine in the world, with reciprocating motion, would tear itself to pieces doing one-fourth as many.

The Admiralty had followed all the trials of *Turbinia* and witnessed her success, and now gave an order for a destroyer to the firm of which Parsons was a member. Thus in 1898 work began upon the *Viper*. She was a small ship, two hundred and ten feet long, twenty-one feet beam, and of three hundred and seventy tons burden. She had two sets of turbines, each with a high- and low-pressure machine working in series, and there were four shafts instead of three.

She developed twelve thousand three hundred horsepower, and her speed over the measured mile was thirty-seven and one-tenth knots. She went astern at fifteen and a half knots. A second destroyer, the *Cobra*, was built on similar lines, but she was not quite so fast, her speed being just over thirty-four knots.

In the Navy they say that it is the worst of luck to name any ship after a reptile, and the fates of these two vessels bear out this saying. *Cobra* was lost in a storm in the North Sea in September 1901, while on her way to the Tyne from the South. It is believed that she broke her back. *Viper* was wrecked in a fog when she ran aground on the rocky coast of the Channel Islands. All the representatives of the Parsons staff and of the builders, as well as most of the crew, were lost in the *Cobra*.

Although these twin disasters were in no way due to the turbine engines, yet they threw a sad damper on the prospects of the Parsons Company, for now the little *Turbinia* was the only vessel afloat having turbine engines. Then Messrs Denny of Dumbarton stepped in and ordered turbine engines for a new vessel they were building. She was the *King Edward*, the first merchant ship to be fitted with turbines. She was quite small, being only six hundred and fifty tons, and was built for service on the river Clyde. On her trials she did well over twenty knots, and the weight of her motors, with condensers, steam pipes, propellers, and all, was only sixty-six tons.

She was so satisfactory that she was soon followed by a second ship, the *Queen Alexandra*. The taunt to the effect that turbines were ‘ steam-eaters ’ failed completely when tables were published showing that these two vessels actually used a fifth less coal than similar ships fitted with reciprocating engines.

Success breeds success. The next thing that happened was that the South-Eastern Railway Company ordered a turbine-engined ship for cross-Channel work. She was the *Queen*, three hundred and ten feet long and forty feet beam. She steamed nearly twenty-two knots. It was found possible to bring her to a dead stop, when travelling at nineteen knots, in one minute seven seconds, a feat impossible with the old-fashioned engines, and she was seen to gather way much more quickly than other vessels. She also burned twenty-five per cent. less coal than her older sisters and required a smaller engine-room staff. The oil consumption was very much less.

The first turbine-engined yacht was the *Emerald*, built in 1903, a vessel of nine hundred tons. She was also the first turbine-engined ship to cross the Atlantic, but the time had now come for the great trans-Atlantic lines to order turbines for their new ships. The honour of being the first to do so belongs to the Allan Line, who built the *Victorian* and *Virginian*, each a big liner of thirteen thousand tons. These carried what were by far the largest turbine engines yet built. The high-pressure turbine for the *Victorian* had a diameter of sixty-eight and three-quarter inches at the high-pressure end, and at the low-pressure end a diameter of seventy-four inches; the low-pressure turbine ran from seventy-four to ninety-five and three-quarter inches. The revolutions to give a speed of nineteen knots were only two hundred and ninety a minute, and the weight of the machinery in each ship was four hundred tons less than for triple-expansion engines.

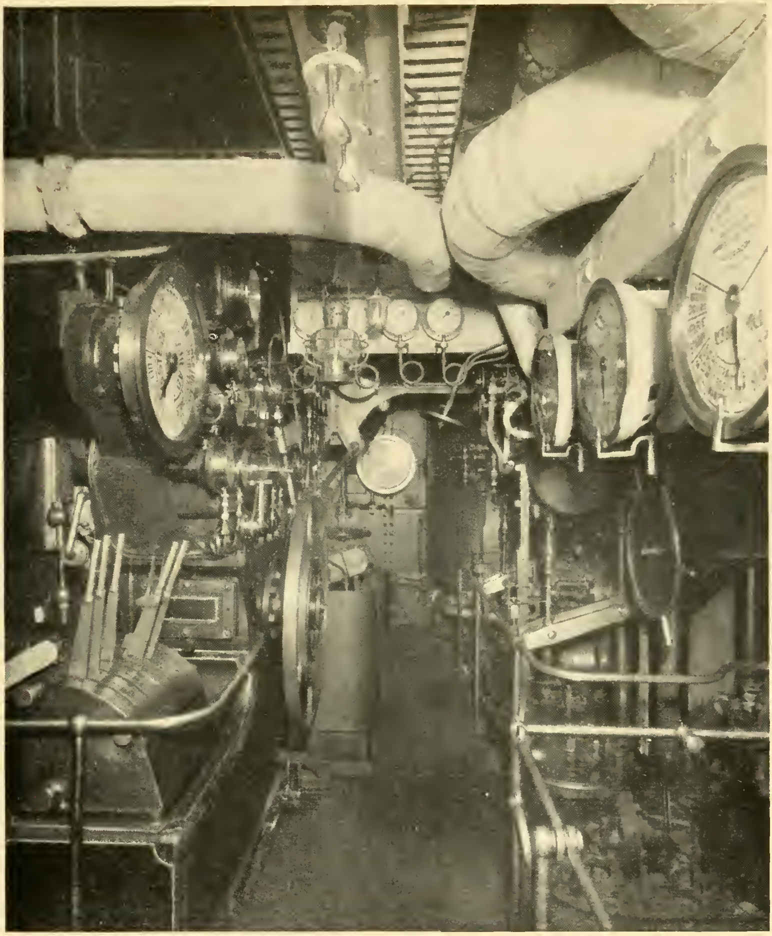
The Cunard Company were the next to act. In 1904 they decided to build two new vessels, each of thirty thousand tons. These were the *Carmania* and *Caronia*. The *Carmania* was to have turbines, and the *Caronia* to have the very last thing in reciprocating engines. Otherwise the two vessels were twins, each being six hundred and seventy-eight feet long and seventy-two beam. Once more the verdict was in favour of the turbines, for *Carmania* proved herself capable of twenty knots as against *Caronia's* nineteen and a half on similar coal consumption, while the space saved in *Carmania* by the adoption of the turbines enabled her to carry more cargo.

The tide was now turned fully in favour of the turbine, and a very large number of new passenger vessels, including two for Japan, were fitted with the Parsons steam turbine. The *Ben-ma-Chree,* built for service to the Isle of Man, surprised every one most pleasantly by doing twenty-five knots on her trials.

Still bigger things were in prospect, for the Government, aware that British trans-Atlantic traffic was threatened by German competition, made a large loan to the Cunard Company for the purpose of building two mammoth vessels of great speed. These were the *Mauretania* and *Lusitania,* and the company decided to fit them both with turbines. The new Cunarders were by far the greatest vessels yet built, being roughly eight hundred feet long, eighty-eight beam, and sixty-six feet deep. The high-pressure turbines were ninety-six inches in diameter, the low were one hundred and forty inches. The *Lusitania* was launched first, and on a forty-eight-hour trial run attained a speed of 25·4 knots. The *Mauretania* did even better, being half a knot faster than her sister. Probably two finer ships were never built, for the *Mauretania* remained the fastest trans-Atlantic ship afloat for more than twenty-one years, and was never beaten until 1929, when the German-built *Bremen* exceeded her record. The *Mauretania* has crossed the Atlantic at a speed exceeding twenty-six knots, while none of her predecessors ever exceeded 23·58 knots.

Large cruisers now being built were engined with turbines. One of them, the *Indomitable,* beat all records for warships by crossing the Atlantic from Canada to England at a speed of 24·3 knots.

So far we have considered chiefly the uses of the steam turbine afloat. But for every turbine installed in a ship there must be a score in use ashore. As we have already



A VIEW OF THE ENGINE-ROOM OF THE R.M.S. "MAURETANIA"

Photo by permission of the Cunard Steamship Co., Ltd.

mentioned, the first Parsons steam turbine was used to drive an electric generator in Cambridge. To-day almost every electric power plant in the world (save those worked by water power) is driven by steam turbines. The tremendous speed of the steam turbine, which was at first a disadvantage in the driving of screw propellers, is of great value in electrical works, where the speed of direct drive is ten to fifteen times greater than was possible with the older type of reciprocating engines.

The speed is, indeed, so great that centrifugal force becomes about twelve thousand times as great as gravity; in other words, every pound weight has an outward pressure of *five and a half tons.* How to counteract such tremendous forces was one of the difficult problems which had to be solved by Parsons when he began to install these plants.

Soon after the Cambridge installation orders began to come in for turbine-driven lighting-plants for ships. The first Atlantic liner to be lighted with electricity was the *City of Berlin,* in the year 1888. This experiment was quite successful, and soon all other lines followed the example.

Turbines are also used for blowing-engines in smelting works. These are simply bellows on a great scale. They take up very little room and are very economical. There is little wear and tear, and very small cost for oil and maintenance. The power is so great that a furnace can easily be blown free if it happens to choke. In one works two small turbo-exhausters took the gas from two hundred and sixty tons of pig iron per day, whereas before they were installed five large exhausting-machines were unable to deal with more than one hundred and sixty tons.

The steam turbine has another use—in rolling-mills. In one Scottish mill designed for rolling steel plates for ships a Parsons turbine was installed with a nominal output of seven hundred and fifty horse-power. But it was found that the actual power available at the shaft ran as high as four thousand horse-power.

Turbines and electro-generators are not the only products of the Parsons works, where you will find a large department devoted to the making of searchlight reflectors. The first of these was made for use in the Suez Canal more than forty years ago, and since that date great numbers have been made for the British and other navies. Reflectors as much as seven feet in diameter have been made in these works. A special feature of these reflectors is the parabola ellipse mirror, in which the beam of light is concentrated on a narrow slit; it then spreads out beyond. This projector can be placed behind a narrow loophole which offers only a small target for shots, yet the whole of the light can be projected in the direction of the enemy.

In 1911 Parsons received the merited honour of being created Knight Commander of the Bath. He is a Doctor of Science in no fewer than six different universities, and an honorary Fellow of his old college at Cambridge. He presided over the British Association in 1919 and is Past President of the Institute of Physics.

The Kelvin Medal is perhaps the greatest honour that can come to the scientific engineer. It is awarded only once in three years, and then only after consultation with the principal engineering institutions not merely of Great Britain, but of the whole world. In 1926 Sir Charles Parsons received this medal. He had already been awarded the American Franklin Medal in 1920. He lives in London, and is as keenly interested as ever in scientific engineering.

CHAPTER XVI

WHERE QUESTIONS ARE ANSWERED

Sir Joseph Petavel and the National Physical Laboratory

IT is surprising how little is commonly known about quite familiar things. How great a strain will any given piece of steel stand without breaking? Why do ships roll in a heavy sea? What happens to an aeroplane if it meets a sudden gust of wind blowing at one hundred miles an hour? What sort of road surface wears longest?

When the technical advisers in any industry or Government Department have conundrums such as these to solve they take them to Teddington, in Middlesex, to the home of the scientific wizards who are at work each day from 9.30 to 5 P.M., in the group of buildings known as the National Physical Laboratory.

So many apparently unanswerable questions has the Laboratory answered that over the entrance there might well appear the legend " We can answer it." They do other things too, as well as answer questions. If you want to measure with absolute precision, to a millionth part of an inch, you must go to Teddington. Or perhaps you have a piece of metal which you want to have heated up to one thousand six hundred degrees Centigrade—almost the highest temperature attainable. These scientists can do it for you. Or perhaps, again, you would like to see an electric spark of a million volts? You can see one at the National Physical Laboratory.

This building, or rather group of buildings—for the Laboratory to-day consists of ten large buildings, with other smaller units, covering altogether twenty-three acres of ground—is the property of the State.

The Laboratory was founded in 1900 by the Royal Society as a public institution whose purpose was to "carry out research, including especially research required for the accurate determination of physical constants, to establish and maintain precise standards of measurement, and to make tests of instruments and materials." That description gives very little idea of the wonders which are to be found within the Laboratory's walls. It is a treasure-house of the latest scientific knowledge, compiled by a staff which has grown from thirty to over five hundred.

Before the War its work was valuable enough, as we shall show. But from 1914 onward, when we were living at the rate of something like a century a year from the standpoint of scientific discovery, and when each morning brought its urgent problem, the Laboratory became indispensable to both Government and industry.

The Government realized clearly the importance of the work done, and in 1918 the National Physical Laboratory became truly national, being made a part of the newly created Department of Scientific and Industrial Research, although the Royal Society continued, and still does continue, to control its scientific activities.

In work of this nature, where there is such need for extreme accuracy and attention to detail, much depends upon the Director. The Laboratory has been fortunate in having as Directors, during its thirty years of existence, two distinguished scientists whose work, done without the least publicity, has nevertheless enriched the nation and proved of inestimable value to British industry.

The first Director was Sir Richard Glazebrook, K.C.B., F.R.S., who after eighteen years in charge of the Laboratory retired in 1918. He was succeeded by the present Director, Sir Joseph Petavel, K.B.E., F.R.S.

We hope that these stories of the greatest scientists of to-day and their work will dispel any idea in the minds of our readers that Science is a ‘ dry as dust ’ occupation concerned with problems remote from life.

There is certainly nothing academic about the work of the National Physical Laboratory. Indeed, there is hardly anything in our industrial life which the organization directed by Sir Joseph Petavel does not touch. In setting out to record the many marvels to be seen at the Laboratory, the only difficulty is to know where to begin.

Let us start with the story of the Froude Experimental Tank. This resembles a super-swimming bath, five hundred and fifty feet long, thirty feet wide, and twelve feet deep. It was presented to the nation by Sir Alfred Yarrow, the famous shipbuilder, for the general advancement of naval architecture.

This tank is one of a series of ‘ testing basins,’ of which the earliest was built by William Froude, at his own expense, at Torquay.

Froude was the first man to prove the value of experiments made with model ships dragged through the water in a tank, and the tank at Teddington was named after him in honour of his pioneer work.

The existence of the Froude Experimental Tank has enabled grave scientists to elevate adventuring with model ships from a sport for the young to an exact science. With wax models that are exact replicas of the vessels under investigation they carry out scientific tests to solve riddles which could be solved in no other way.

Many years ago these tanks proved their value. For instance, models of Sir Thomas Lipton’s first famous *Shamrocks* were made and tested in the private tank at Messrs Denny Brothers’ shipyard at Leven, years before the War. Indeed, in the erection of *Shamrock II* no fewer than sixty models were made, the experiments lasting over a period of nine months. Over and over again the great tank at Teddington has proved its value to the nation.

Let us give one example. A giant Atlantic liner collided with a small cruiser in the Solent, near Southampton, a few years ago. Happily there was no loss of life, but the damage gave rise to difficult questions regarding the responsibility for the collision. The case remained at a deadlock until the Admiralty put forward a theory which led to a solution.

The authorities said that the collision might have been caused by the wash of the giant liner sucking the small cruiser toward her.

It might be true, or it might not. How could the theory be tested? Obviously they could not arrange another collision. At least, not with real ships on the Solent. But the scientists, with the aid of the Froude Experimental Tank, could stage the collision—a hundred times if necessary—under conditions exactly parallel with those under which it had occurred. So to Teddington went the President of the Court, counsel, and witnesses.

First were built as neat models as ever delighted the heart of a boy of any age up to sixty. Constructed of yellow paraffin wax, they were perfect scale replicas of the giant liner and the cruiser. The liner even had passengers, crew, and cargo represented by lumps of lead, and little bags of ballast, while the cruiser was complete down to her ram and rudder. Both models were fitted with tiny electric motors and screws.

Then before the lawyers and naval experts the Solent collision was re-enacted. The depth of water in the tank was proportionate to the depth of the sea beneath the vessels when the accident occurred.

To reproduce the speed of the ships the scientists brought the 'bridge' into operation. This is a steel structure spanning the width of the tank, weighing fourteen tons, and set on rails at either side, along which it is electrically driven at a variable speed. Attaching the two models to the undercarriage of the bridge, the models being relatively the same distance apart as were the warship and the liner at the time of the smash, they switched on the current, and the two boats moved off on their voyage, while all those interested stood above, taking notes.

The models steamed on their course at an actual speed of sixteen knots. Then came the thrilling moment and the crash. With their own eyes the President, counsel, and witnesses saw just what happened in the Solent. They could see for themselves how the liner's wash affected the small cruiser. Then the collision was repeated for them again and again, so that they should not miss the slightest detail.

The evidence of the Tank tested the expert's theory, and the lawsuit was settled.

Through increased activity in our shipyards and improved methods in shipbuilding the Tank is being kept busy, and much ' shipbuilding ' is going on in the miniature shipyard next to it, where those exact models in wax are constructed.

One of the problems recently tackled by these scientists was associated with a difficult branch of shipbuilding, the designing of fruit-carrying steamers, whose essentials are ample cargo space and speed. Speed raises the question of the stream-lining of hulls, and the systematic research carried out at Teddington has led to results greatly beneficial to our shipyards. For example, in the case of a ten-knot tramp boat it was found possible, after experiment with hulls of various shapes, to effect a reduction of no less than thirty-five per cent. in horse-power without altering the speed. In another case, where a nineteen-knot ship was involved, ten per cent. of the horse-power was saved, which for that one ship was equivalent to a reduction in the coal bill of about five thousand pounds a year!

Speed, too, can be tested in anticipation with the aid of this invaluable Tank. During the War the world's fastest destroyer was built for the British Navy after experiments in design had been made at Teddington, and if Britain regains the blue riband of the Atlantic it will quite possibly be through similar trials at the Laboratory having proved which design could be expected to produce the maximum speed. Thus our shipbuilders are no longer building 'in the dark,' for their ideas can be tested quickly, under the appropriate conditions, by men who have made the sailing of toy boats the handmaiden of Science.

If waves are wanted they can be produced by a special device. If a shipbuilder wants to see how his projected boat will weather a violent Pacific storm, exactly equivalent conditions can be produced. There is also a false bottom to the tank; this can be raised to give the effect of shallow water.

The use of wax models contributes also to elasticity in the experiments. If the first design does not give satisfactory results, then a little can be added to the model here or shaved off there, and a vessel of new and improved shape put through its trials. This can be done again and again, if need be, until the perfect line has been discovered.

The National Physical Laboratory will investigate anything associated with water-navigation. In one year it tested eighty-one models, representing fifty-nine different designs. The Tank is used for other experiments too. For instance, the famous Schneider Trophy 'planes were tested, in model form, in the Laboratory, and experiments have been carried out with the object of illustrating the action of seaplanes when rising from the water.

The scientists at the Laboratory have even studied the rolling and tossing which most of us associate inevitably with seasickness. One of them specializes in studying the reasons why vessels roll and pitch, and the effects of this buffeting by the waves. This man, whom many of our readers will regard as a true martyr in the cause of Science, goes for sea voyages with an ingenious recording instrument as his companion. But his vogages differ from other people's. He deliberately sets out in search of rough weather. He is so keen to endure the worst the sea can do that passages are booked for him in the winter on cargo boats, when the Atlantic can be relied on to satisfy his appetite for storms.

Among his trophies is a graph of pitching in a 10,000-ton cargo-boat during a big storm which makes the land-lubber sick to look at. And he will tell you exultantly of a roll of thirty degrees he once experienced; this he has carefully stored among the data he is collecting for an effort to make vessels steadier in bad weather—surely an effort for which humanity will thank him.

Important as are these researches, on the sea and in the famous Froude Tank, they are only one part of the work of this wonderful laboratory, which does many other things just as remarkable and valuable—indeed, the activities of the National Physical Laboratory are so varied and extensive that it would need a book much larger than this to give an adequate picture of the real wonders of its work.

There are six other main sections: Physics, Electricity, Engineering, Metallurgy, Aerodynamics, and Metrology.

Not long ago the Engineering Department had a very interesting problem to tackle. The House of Commons had complained of bad ventilation, so the problem was turned over to the National Physical Laboratory. There the scientists built a scale model of the House, and from their observations were able to make valuable suggestions for improving the air breathed by Members.

Next door to that model in the Engineering Department is a fearsome-looking steel structure whose function it is to test railway couplings. It is known as an impact-testing machine, and the blow it delivers corresponds to dropping a mass of one ton through five feet. By repeatedly dropping a ton weight on to a coupling or a chain it is possible to discover the precise strain or stress which it will stand in actual use. The railway companies adopt only the designs which have proved themselves able to stand a strain many times greater than any they are likely to endure on the line. Thus the public is safeguarded.

The Laboratory has several machines for doing damage to metals. In fact, some of its scientists are at work all day smashing up pieces of metal that have been made with great care. One machine stretches steel rods to discover how great a strain they will withstand before breaking, another squeezes metals, a third twists them, and yet another bends steel springs backward and forward about a thousand times a minute for hours on end, all the time automatically counting the number of times the spring bends. Finally the machine shows the number of times the spring can be bent before it gives way. This type of experiment has proved valuable in testing the springs of motor-cars; and the springs on the car or bus in which you ride are better and safer than they would be were it not for this work.

These experiments are linked up with the very important question of ' fatigue ' in metals.

Now that industry is constantly building machines for working at terrific speeds under high pressures, engineers must know how much strain a metal will stand.

Occasionally we hear that the steel arm of a crane has cracked, perhaps causing loss of life. After an event such as this the maker of the crane will send a sample of the metal to the Laboratory for testing, and the experts will tell him why the metal failed.

Testing the hardness of a metal is really quite a simple matter. A diamond is pressed into it, and then the resultant marks are examined under a powerful microscope.

The Metallurgy Department at Teddington is also very interested in this problem of ‘ fatigue ’ of metals, but the means they use are furnaces, microscopes, and chemical analyses.

There you can see metals heated to the highest attainable temperature. They do this with what they call their high frequency valve furnace, which will raise the temperature of a metal until it reaches the staggering figure of one thousand six hundred degrees Centigrade. The valves, much like ordinary wireless valves, are about two feet long, and cost seventy-five pounds each!

More amazing still is the fact that this intense heat is generated in the body of the metal itself, in such a way that the outside of the furnace remains cool enough to be touched.

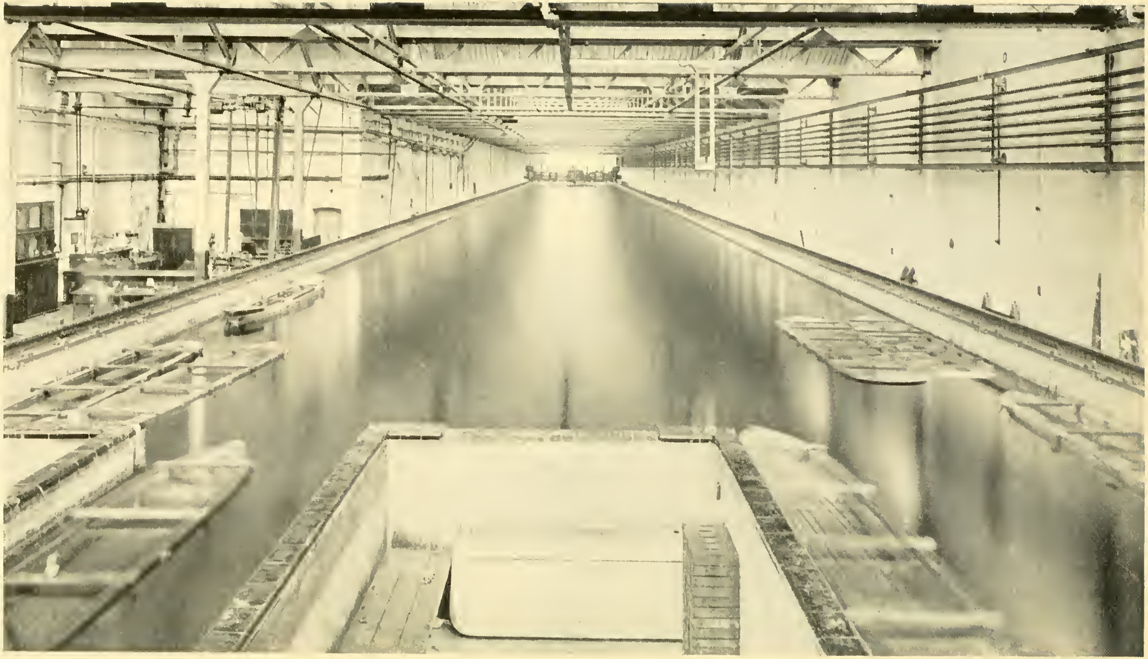
In another department the problems of the motorist are dealt with. Every motorist knows the danger of skidding on wet and greasy surfaces, but how many know that at Teddington scientists are every day seeking to solve the problem? They have there a skidding machine —a motor-cycle and side-car, with a wheel specially made for skidding. Instead of having the dials and gadgets dear to the heart of the youthful motor-cyclist, this machine is decorated with apparatus which records all that happens when it is deliberately skidded over a prepared surface.

Another road problem in which these scientists are interested is the effect of wheels on road-surfaces, and another is the search for the ideal road-making material.

A lorry which can be fitted with various kinds of wheels is used in tracking down the type of wheel that is responsible for most road damage. But the most remarkable machine is the road-surface tester, a weird contraption having eight wheels, connected with a central pivot, which rotate in a circular bed. It is like a roundabout without a top. If you invent a new surface for roads which you believe will wear longer than any other, take it to Teddington. There they will lay a strip of your material on the circular track and set the eight wheels in motion. For seven hours a day, week after week, the wheels will travel over that prepared track, until the scientists know just how long the surface will stand the 'traffic,' and can compare the result with the carefully compiled statistics relative to other road materials.

One more instrument in this department of wonders must be mentioned. It is a little machine so sensitive to earth tremors that it will record the passage of traffic several hundreds of yards away. This will be used for making observations of the actual blow that a wheel delivers to the road; the testing-ground will be an artificially prepared rut.

Apart from the Tank, however, perhaps the most interesting feature of the Laboratory is the Aerodynamics Department, where are to be found the wind tunnels. These are fearsome to the eye. Imagine a huge wooden funnel, fourteen feet broad and seven feet high, supported on steel legs, with a mighty propeller at one end which at a maximum speed can suck air through the funnel at one hundred feet per second, which means that twenty tons of air pass through the tunnel every minute. A man would be swept off his feet by such a blast. Even an aeroplane would find it difficult to face the storm—and that is just why these wind tunnels were built. For they are the airman's friend, and with their help the scientist has collected much valuable information about the pressure of wind and air on aeroplane wings and fuselages. Otherwise this could only have been collected slowly, and through infinite risk of life and limb in the air itself.



THE WILLIAM FROUDE NATIONAL TANK

Presented by Sir William Jarrow to the National Physical Laboratory.

By permission of the Controller of H.M. Stationery Office

It is impossible to study a model aeroplane when it is actually flying. At Teddington, therefore, they have adopted the expedient of fixing the model and forcing the air past it. Specially designed apparatus records how the wind-pressure affects the model, and the velocity and direction of the air-flow past any particular part of it.

This is important, for if anything in the design of a 'plane produces air-eddies in any given wind-direction the lifting-power of the machine will be reduced. How then can it be proved that any given design will produce an even current as it travels through the air? Or, if it produces eddies that cause it to 'drag,' how can those eddies be measured and the cause of them exposed?

These seem to be impossible questions, but the National Physical Laboratory has answered them by creating a simple apparatus. They fix a fine platinum wire, suspended between two prongs, to that part of the model which they wish to study, and an electrical current is passed through the wire, heating it. Then the wind is turned on. If there is an even current of air, with no obstacles to produce an eddy at the point under test, the wind will cool the whole length of wire evenly, and the instrument which carefully records every variation of temperature of that little wire will show that result. But if eddies are present in the wind-force at that given point, the wire will one minute be in a fast current of air —and therefore cool—and then for a fraction of a second in a slower current or a calm produced by the eddy. In that fraction of time the temperature of the wire will increase, and that increase will be recorded, thus proving conclusively the presence of unequal air-currents due to the design of the machine.

That is one small example of how these wind tunnels lay bare secrets which might otherwise not be revealed except by years of research. Investigations have also been made with airship models, and these have been supplemented by experiments on airships in actual flight. Parachutes, windmills, aeroplane carrier ships, and the wind-resistance of planes, spheres, cylinders, and spheroids —all have been made the subjects of tests, and this methodical work has yielded a mass of information of the utmost value to the aircraft industry.

Yet another department of this wonderful institution is that devoted to Metrology. Here are kept the standards of measurement which are used by us all, and here new standards are devised when these are called for by discoveries of new materials or processes.

When we talk lightly of so many yards or metres in length, pounds or grammes in weight, seconds or minutes in time, so many degrees of temperature or ohms of electrical resistance, do we realize that somewhere there must be an institution capable of making absolutely accurate measurements of these quantities? Many of them are defined by law, and it is of the most vital importance that all should be fixed. Then when one remembers the manufacturing processes, where precision is required for scientific work, it seems doubly important that the standard should be fixed with the greatest possible accuracy.

At the National Physical Laboratory may be seen a brightly polished bar with faint scratches on its surface. It is a copy of the Imperial standard yard. As most people know, this is the distance between two points marked on a bronze bar kept in Trafalgar Square. Another bar—this of platinum—measures the metre. Against these absolutely accurate measures are tested yards and metres submitted to the Laboratory by commercial firms, Government Departments, and others.

The actual process of testing is too technical to be described in a short space. It consists in placing the yard to be tested beside the standard yard in a water-bath to keep them both at the same temperature, and then in reading the minute scratches on the official standard yard by means of microscopes. The yard under test is then compared with the standard, and thus the slightest divergence is revealed. An error of only one-millionth part of an inch can be detected unerringly.

That surely should be accuracy enough for anyone. But the Laboratory is not yet satisfied. Its workers are now engaged in defining a yard in wave-lengths of light, because any metal, whether steel, platinum, bronze, or anything else, is liable to alter in length during the course of years, and it is important that at no time should the standard yard or metre change by even an infinitesimal part of an inch. For while a fraction of an inch more or less may be of no account to a woman buying cretonne, it is vital to the manufacturer of ball-bearings, each of which must be of identical size if there is not to be friction, or to the manufacturer of pistons for motor-cars, for all these must fit absolutely if there is not to be loss of power.

It is the same with the measures of weight. These are stored in the Balance Room, where the staff are at work testing weights for scientists, analysts, chemists, and others who need absolutely accurate standards for their work. These weights are tested against the standard weights in scales so sensitive that they have to be insulated against changes in temperature. Even the heat of the operator's body might upset their accuracy, and the tests are therefore made at a distance by means of prismatic reflectors.

Watches, clocks, chronometers, and other time-measuring instruments are tested in a similar way against the Laboratory's standard clocks, which are in turn checked three times a day by time-signals from Greenwich, Paris, and Germany.

Close by is the Physics Department, which tests clinical thermometers at the rate of nearly sixty thousand a month. Before a clinical thermometer is passed by the

Laboratory as accurate it must register any temperature to within one-tenth part of a degree Fahrenheit.

In yet another part of this building experiments are conducted for the purpose of solving cold-storage problems. Here scientists are at work studying the heat-insulating properties of different materials and investigating methods of regulating the temperature, humidity, ventilation, etc., of cold-storage plants. A member of the staff recently travelled to Australia in order to investigate the conditions affecting the transport of apples to this country, and to advise on the provision of suitable instruments for making the measurements of temperature necessary to ensure that the fruit reaches this country in perfect condition.

At Teddington also is the British Radium Standard; by this is measured the amount of radium contained in any sample of radio-active ore submitted. Here also is tested the protective value of materials used in X-ray installations, and the Laboratory also examines the X-ray equipment used in hospitals.

It is no exaggeration to say that there is hardly a single department of public life with which the National Physical Laboratory is not concerned. Propeller designs, the efficiency of gears and lubricating oils, steam-pipe insulation, the strength of cylinders for compressed gas, the heating of underground mains, wireless valves and transformers, the manufacture of optical glass, the analysis of tides, the velocity of projectiles, aeroplane fabrics—the scientists of the Laboratory are interested in them all, and in many more subjects of scientific inquiry which we have not the space to mention here.

But there is one more department which must be mentioned. This is the High-voltage Laboratory, where a million-volt electrical current can be produced at will.

It is an enormous hall, forty feet high, and at one end of it there are columns of intricate steel apparatus, connected by arms with projections from the ceiling. Those six columns support three transformers, forming the high-voltage testing-plant which will play its part in the new national electricity scheme now in course of development. For that plant can produce a current at one million volts and a frequency of fifty cycles a second—that is to say, through that apparatus can be flashed fifty electrical charges of one million volts, backward and forward, in a single second.

CHAPTER XVII

SAFEGUARDING THE NATION

Sir Robert Robertson and the Government Laboratory

EVERY day thousands of Londoners pass close to one of the most interesting institutions in the City, yet probably not one in a thousand of them even knows of its existence. We refer to the Government Laboratory, which stands in a narrow passage just west of the Law Courts and within a few yards of the eastern end of the Strand. The building itself is not likely to attract attention, but inside it there are great rooms full of chemical apparatus, and there is a staff of some two hundred chemists busy with an amazing variety of work under the direction of the Chief Government Chemist, Sir Robert Robertson.

Sir Robert is a scientist of many different interests and achievements. During the War he was one of the principal experts on explosives, and if you wish to realize the extent of his knowledge on this particular subject you should refer to a lecture which he read before the Chemical Society on " Properties of Explosives," which is published in the *Transactions* of that society.

But his special hobby now has nothing to do with explosives. It takes the form of studies in the infra-red region of the spectrum. The results of some of his experiments in this field have been printed in the *Proceedings* of the Royal Society, but they are too technical for a book of this kind, and it will be more interesting to consider here the work done under Sir Robert's direction in the Government Laboratory.

Since 1911 the Government Laboratory has been a separate department under the Treasury, and furnishes advice and assistance to various public departments in matters demanding chemical knowledge. While its scope is now greater than that of work for Customs and Excise, it had its origin in laboratories created for work in connexion with dutiable substances. Ever since import duties were first levied on such imports as tobacco and tea, and excise duties on spirits, it has been necessary to have skilled men to examine these goods.

For instance, no one can tell just by tasting beer how much alcohol there is in it. The same is true of brandy, whisky, and other spirits, all of which pay duty according to the amount of alcohol contained in them. Methods of testing these beverages had therefore to be invented. This was part of the work of the first Government chemists, and it is still that of their successors in the twentieth century.

As we all know, the tax on alcohol was heavily increased during the War, and this fact has made the Excise and Customs authorities more particular than formerly. One of the largest departments in the Government Laboratory is devoted entirely to testing various imported goods for their alcohol content. Alcohol, of course, is to be found in many things other than liquor. It is to be found, for instance, in scents, photographic developers, varnishes, and in many kinds of medicine. As many as one hundred samples of drugs and scents are dealt with in this laboratory in one day.

The instrument used for testing the specific gravity of beer is the saccharometer. This was invented nearly two hundred years ago, and it is still in use. The number of analyses and examinations of beer made in the Excise branch runs to many thousands yearly. Samples of ‘ wort ’—that is, beer before fermentation—are constantly being tested to check the declaration of gravity made by the brewer—for it is upon this ‘ original gravity ’ that duty is levied—and samples of finished beer are brought in from public-houses in order to discover whether the liquor has been adulterated. At one time it was quite usual to find that the beer had been diluted with water, but heavy fines have discouraged those guilty of this mean swindle.

Formerly spirits were tested only by an instrument called the hydrometer, but this method failed badly when colouring or sweetening matter had been added, and in 1881 a change was made to testing by distillation.

Spirits are usually stored in wooden casks, and the wood absorbs a considerable quantity of alcohol. Traders discovered a means of extracting this alcohol from the wood, with the result that every barrel yielded two to three gallons of spirits which were practically duty free. But the chemists of the Government Laboratory caught on to this ingenious bit of tax-dodging, and 'grogging,' as it is called, no longer pays.

Not only alcoholic liquors, but ginger beer, herb beer, and similar temperance drinks, are all tested in the Laboratory. The law allows two per cent. of proof spirit in these, but a surprisingly large number are found to exceed this limit. Ginger beer is most often at fault. Many samples are found to contain as much as two per cent. of alcohol, and one was found to contain four per cent., making it more intoxicating than an ordinary light beer.

Second only to drink, from the standpoint of tax returns, is tobacco, and a whole department of the Laboratory deals with tobacco and nothing else. All tobacco entering the ports of Great Britain pays duty, but there is of course much waste, or offal, on which a rebate is allowed to the manufacturers. Waste includes stalks, 'shorts,' and 'smalls.'

A close watch is kept upon manufactured tobacco. Sir Robert's chemists take very good care that the legal limit

SIR ROBERT ROBERTSON

Photo by Russell, London

of thirty-two per cent. of moisture is closely adhered to. This thirty-two per cent. includes the natural moisture of the leaf, which varies from thirteen to seventeen per cent. Tobacco factories are inspected by Government officials, and any manufacturer who attempted to sell tobacco adulterated with "leaves, herbs, plants, moss, weeds, ground or powdered wood, chicory, etc."—as the Statute runs—would soon be detected and heavily fined.

The Laboratory has ovens for drying tobacco and enabling its workers to estimate exactly the amount of moisture. There are also special furnaces for carbonizing tobacco, so that the proportion of ash can be estimated. The tobacco to be burned is placed upon dishes made of silica, which is unaffected by heat.

It is interesting to know that it was tobacco adulteration which first made the authorities feel a need for the help of the chemist, and thus came about the erection of a small Government laboratory in 1843. This was the modest beginning of the present institution.

One of the principal tasks of the Government Laboratory is to protect the people of this kingdom from being swindled or poisoned by adulterated food and drink. Adulteration of food is one of the oldest crimes. We have records of flour being adulterated as long ago as the reign of King John. The Adulteration of Coffee Act of 1718 refers to evil-disposed persons who make use of water, grease, butter, and suchlike materials for addition to coffee, "whereby the same is rendered unwholesome and greatly increased in weight, to the prejudice of His Majesty's revenue and the health of his subjects."

In 1843 Mr Phillips of the Inland Revenue stated that there were in London alone at least half a dozen factories for the purpose of redrying tea leaves. These spent leaves were mixed with those of sloe, sycamore, horse-chestnut, and other plants, and coloured with green vitriol and indigo, and gave a most poisonous brew.

We ought to be thankful that the Government chemists of to-day save us from abominations such as these, inflicted upon our grandparents. In 1860 Parliament passed the first Act dealing with adulteration, but because there were few means of enforcing its provisions it did very little good.

At last in 1875 came the Sale of Food and Drugs Act, the first real attempt to cope with the evils of adulteration. Tea, coffee, pepper, and various other foodstuffs were already examined by the State chemists, but the new Act (which was followed by the Margarine Act of 1887 and other similar Acts) greatly increased their work. Indeed, it would have been impossible for any one body to safeguard the food of the whole nation, and Parliament therefore ordered local authorities to appoint public analysts, who now do most of the food analysis. When a sample is taken, one part goes to the Public Analyst, one to the vendor, and a third part is reserved for the Government chemist in case of a dispute between the parties.

In 1900 there was a terrible scare about arsenic in beer. A number of people died from this cause and a still larger number became very ill. The trouble was traced to ‘ invert ’ and other sugars used in the brewing of malt liquors, and the whole of this sugar was destroyed. Beer-drinkers are no longer in any danger of being poisoned in this way. Arsenic, however, has been found in other substances, such as paint, wallpapers, and certain toilet preparations. Frequently samples of these are analysed in the Laboratory. The poison in yew leaves, which is so fatal to cattle, was once the subject of a lengthy research at the Laboratory; on another occasion glazes were tested for lead. The amount of lead in glazes is now restricted by law, with great benefit to the health of the workers employed in potteries.

A poison which claimed many victims was the white phosphorus formerly used in the manufacture of matches.

The workers suffered from a dreadful disease called 'phossy jaw.' It was proved that for making matches red phosphorus was just as good as white, and that it was much less dangerous for the workers. Now one of the tasks of the Government Laboratory is to test imported matches for the presence of white phosphorus.

Samples of a very large number of foodstuffs are analysed yearly by the staff of the Government Laboratory, and special attention is paid to butter, margarine, milk, and cream. Frauds to be watched for include the substitution of margarine for butter, and the use in imported butter of injurious artificial colouring or preservatives. The amount of water which butter may contain is laid down by law; it may not exceed sixteen per cent.

You may perhaps wonder how the analyst discovers foreign matter in butter. One method involves the use of a specially constructed instrument. Pure butter melted has a definite angle of refraction when a ray of light is passed through it. Since this angle is known any difference from it may be an indication that the butter is not pure. The amount of butter fat in any sample can be determined by distillation of the volatile acids. There are several ways of getting at the truth, and of bringing the adulterator to book.

It might be expected, after all this, that offences would have been ended, yet the report of the Ministry of Health for the year ending March 31st, 1929, records an increase in the adulteration of the nation's food. Of 129,034 samples examined, 7524 were found to be adulterated—that is, nearly six per cent. Some cases were peculiarly scandalous. For instance, paraffin wax was found in three samples of suet, and a sample of flour contained a quantity of fungus. Mustard was mixed with maize flour, and sand was discovered in mixed spice, while samples of cod-liver oil tablets contained no cod-liver oil whatever. Jam was found to be artificially dyed and to contain salicylic acid, while wines too were adulterated with the same acid and with glucose. A sample of anchovy paste contained fourteen per cent. of ash, mainly iron oxide, this having been added to colour the paste.

Worst of all were the Easter eggs made of chocolate which generally contained glass, zinc, copper, and sawdust, and the custard powder containing more than a trace of arsenic.

The scope of the work done by the Government Laboratory is immense. Indeed, there is hardly any Government Department which does not at times make calls upon it. The Public Prosecutor, the Record Office, and even the Geological Survey all employ the services of its analysts.

Often it is the duty of the Public Prosecutor to proceed against forgers. In such a case the only evidence against the accused may be the forged cheque, and it is the task of the prosecution to prove that this is a forgery, with the aid of the Government Laboratory. There is a department in the Laboratory where the visitor is shown cheques, or rather enlarged photographs of cheques, which have been sent for this purpose. And if the forger only knew how clearly his forgery shows up under the camera and the ultra-violet rays he would certainly think twice before attempting another such swindle. In one case the amount of a cheque for thirty-one pounds had been changed to one hundred and thirty-one. The figure 1 had been inserted and the word 'one' written in. Then all the writing on the cheque had been gone over carefully with Indian ink. The original was good enough to deceive a bank cashier, but the photograph showed up the forgery so plainly that a child could see it.

Since the tax was put upon bets, dishonest bookmakers have frequently altered the books in which they kept record of their transactions, in order to avoid paying the tax. Here again the cameras and rays of the Laboratory have been used to show up the erased figures. However carefully they may be rubbed out, they come up clearly in these interesting photographs.

Again, by the use of chemicals unscrupulous people have been able to delete the markings on used unemployment stamps, and so to use them over again. Yet once more Science has proved too clever for the swindler, who has found himself heavily fined for his efforts to get the better of the State.

At the Record Office in Chancery Lane there is the most wonderful collection of ancient documents in existence, and not the least interesting is Shakespeare's marriage settlement. Not long ago the staff at the Record Office were shocked to discover a blot of ink on Shakespeare's signature. No one remembered having seen this before, and there was doubt as to whether it was an old blot or a new one. Off went the document to the Laboratory, and almost at once came the answer that it was a *new* blot. A test of the ink proved it to be made from aniline dye, which of course did not exist in Shakespeare's time. The blot was removed and the document returned to the Record Office.

The great increase in the use of gas and electric light has reduced the number of oil lamps used for lighting purposes, but on the other hand there has been a very great increase in the sale of oil-burning lamps for cooking and heating. Oil used in these lamps must not ' flash ' —that is, give off inflammable vapour in a closed vessel— at a temperature below one hundred degrees Fahrenheit. Many samples of oil are tested yearly in the Laboratory to make sure that they comply with the law. What is called the Ableclose test is used for this purpose, and all kinds of oil are tested, including samples of oils used in lighthouse lamps, sent by Trinity House.

' Fire-bugs '—as they call them in America—have been unusually busy during the past few years. They always are when trade is bad, for often a fire is the only way to stave off bankruptcy. Petrol has always been the mainstay of the fire-raiser. The old trick was to fill a bladder with petrol and hang it over a lighted lamp. Within an hour or so the heat caused the bladder to explode; then blazing petrol was scattered all over the room, and everything was instantly afire.

But Science soon outwitted the fire-bug. After fires that aroused suspicion, Government chemists tested small fragments of paper, carpet, or cloth, and by steam-distilling were able to discover whether petrol had been used to start the flames. Their greatest triumph was when the only relics brought them after a fire of this kind were some fragments of celluloid. The celluloid was not merely charred, it was burned; yet even so they were able to decide that it had been in contact with petrol. Thus was revealed the most ingenious device yet adopted by the professional fire-raiser, who in this case had strewn the floor of the doomed building with celluloid balls filled with petrol. His guilt was clearly proved, and instead of pocketing the insurance money he received a sentence of three years' penal servitude.

It is hard to believe that less than a hundred years ago water was pumped direct from the Thames near Hungerford Bridge for the use of Londoners. Small wonder that cholera swept the city and that people died in thousands from typhoid and similar diseases. The fall in Great Britain's death-rate is due as much to the provision of pure drinking-water as to all the great improvements in medicine, and one of the tasks of the Government chemists is to keep an eye upon the purity of water-supplies. Country districts require these services more than great cities, which have their own municipal analysts. We all owe a very great debt to the late Sir Edward Frankland (President of the Royal College of Chemistry in 1865) for devising a means of testing the qualities of drinking-water, and for the work he did in pressing for pure supplies.

Water is such a powerful solvent that it is not at all easy to obtain it in a pure state, and springs which were perfectly good in the past have often been contaminated by the spread of buildings. Take the case of Maidstone, a town which enjoyed the reputation of being very healthy, with an extremely low death-rate and a freedom from infectious disease. In 1897 a terrible plague of typhoid overtook it, but chemists got to work at once, and within a very short time traced the infection to the water-supply.

In spite of London's excellent supply of well-filtered water, many people long persisted in using old wells, from which the water came up cool and fresh. But these very waters which appealed so strongly to the eye and the palate were often proved to be most dangerous. There was, for instance, the pump near St Bride's Church; the water from this was famous for its cleanness and coolness, yet when analysed it was shown to be poisoned with products of the neighbouring graveyard. Since printed warnings were of no effect the authorities were forced to padlock the handle of this pump.

The Revenue authorities use quantities of hydrometers, thermometers, and measuring vessels in their work of gauging and sampling, and it is one of the many tasks of the Government Laboratory to test these before they go out.

There does not seem to be anything too great or too small to come under the careful eyes of these Government chemists; their inquiries range from the condition of our telegraph-poles to the genuineness of a postage-stamp.

In one department you may see a specimen of steel being tested for sulphur. The steel is dissolved in acid and the free sulphur converted into lead sulphate. In another room you may notice a worker testing a small piece of painted wood to find out whether the contractor has laid on three coats of paint as he had agreed to do or only two. It may be mentioned that in the case which came under the writer's notice it was speedily proved that there were only two coats, and the contractor had a bad quarter of an hour.

In still another room the writer saw a shelf full of soda-water bottles; on inquiry it was learned that these were filled with sea-water. There were samples taken from the seas of all the world, and they were being tested for the quantity of salt contained in each. There is, for instance, far more salt in the North Sea than in the Baltic, and more in the Atlantic than in the Mediterranean.

Knowledge of the salt content of these various samples helps the chemists and others to determine the drift of currents, the rate at which the spawn of fish is carried, and, to some extent, the amount of 'plankton'—fish-food—which exists in various seas or oceans.

One more achievement which is well worth recording is the recovery of the radium used during the Great War. Radium, as we all know, is very scarce and costly. At comparatively small expense these chemists have succeeded in restoring to its original state no less than ninety-eight per cent. of all the radium used in our war equipment. Tiny fractions of luminous paint had to be scraped from gun- and rifle-sights, from compass-cards and aeroplane-indicators. This work alone has saved the country thousands of pounds.

There is no other place in England, perhaps no other place in the world, which provides a finer example of the triumphs of applied science than our Government Laboratory. While there is, of course, a good deal of routine work, there is no knowing when some new problem may arise. Then the whole burden of responsibility falls upon the shoulders of the principal chemist, who may have to devise new apparatus and map out new plans of attack or defence. He must therefore, as you will realize, be versatile. If he were not also very modest, we might have written more about him personally, and a little less about the great laboratory under his control.

CHAPTER XVIII

DR SUNSHINE

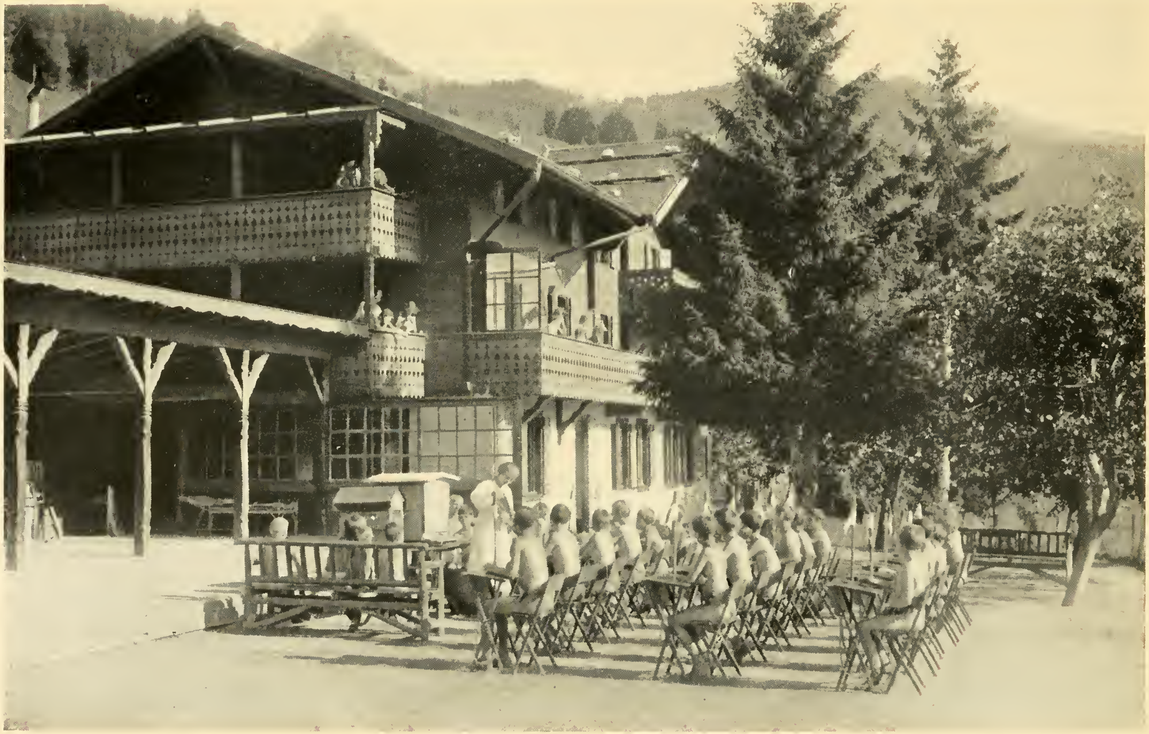
How Dr A. Rollier Founded the Most Wonderful School in the World

MANY remarkable medical discoveries have been made during the past forty years—discoveries which have given doctors new weapons for use in the age-long fight with disease—but no recent development in medical science is more inspiring than the rediscovery of the sun as the great healer.

We write rediscovery, for the healing powers of the sun were well known in the days of ancient Greece. Then for centuries this great natural source of healing was neglected, while men and women nursed their sickness behind walls that shut out the healing ultra-violet rays. Those centuries were the real Dark Ages, and it was not until the closing years of the nineteenth century that a young Dane, Dr Niels R. Finsen, began to study the action of sunlight on certain diseases, and particularly its action in cases of lupus and other forms of what had until then been called surgical tuberculosis.

Dr Finsen was mainly interested in artificial sunlight —the reproduction, by scientific means, of the valuable ultra-violet rays when the natural sunlight was not available.

The wonderful results which Finsen obtained persuaded other investigators to study the action of sunlight itself. Thus began what has been called the modern 'sun-worship.' That was about thirty years ago, and so rapidly has sun-worship spread that to-day many towns, including London, make provision for sun-bathing, so



THE SUNSHINE SCHOOL AT WORK

Pupils and patients learning their lessons in the open air at Dr Rollier's hospital in Switzerland.

that children and adults can expose their bodies to the beneficial rays. In any Northern country, also, there are few modern hospitals where artificial sunlight lamps are not employed as a valuable aid in the conquest of disease.

It will be remembered that artificial sunlight was employed during the King's long illness in 1929, a treatment which could not have been administered but for the work of the pioneers who proved the value of sunlight in sickness and health.

Foremost among these pioneers is a Swiss doctor whose name is still unknown to tens of thousands of those who have benefited by his work. That work is carried out in the Swiss mountain village of Leysin, far away from great cities, by Dr Rollier, who although he has never sought fame will certainly be remembered as the man who demonstrated the wonderful healing powers of the sun. For nearly thirty years he has tended his patients in a hospital where surgeons and medicine are unknown. These patients come to him with hunched backs, tuberculous limbs, and twisted bodies. He calls in the aid of the sun, the fresh air, and good food. That is all. And presently the patients go away, their bodies miraculously made beautiful and a new light of health in their eyes.

More wonderful still is the sunlight school at Leysin, a school in which Dr Rollier's younger patients learn their lessons sitting on the snow slopes, clad only in a pair of drawers, while Dr Sunshine cures their bodies and makes them the strong, healthy children they were meant to be.

We are not sure that Dr Rollier ought not to have been given a place in one of our previous volumes devoted to modern adventurers, for in our generation there have been few adventures greater than that on which he embarked when in 1903 he began to use the sun-cure for the treatment of surgical tuberculosis.

In 1903 those suffering from this terrible form of disease turned for cure to the surgeon rather than to the doctor. The knife was used, limbs were amputated, so that if the patient was cured it was only after his body had been scarred or mutilated for life.

The best way to tell how Dr Rollier has changed all this is to describe that amazing school on the snow-bound slopes of the Alpes Vaudoises. For although the school is only a part of the wonderful hospital (to-day there are thirty-seven *cliniques*, with over one thousand patients), it is the most striking part of it. It is the only school in the world in which diseased bodies are made beautiful while the children learn their lessons.

On a day when the school is in session you may see a class of boys starting out for their lessons. All of them have been sent to Leysin because they could not be cured anywhere else. Now they start out over the snow-covered slopes, clad only in a loincloth and boots. Yet as they glide downhill on their skis, with portable stools and desks on their backs, they are not cold. Their bodies are functioning perfectly, they are stored with sunlight.

On they go until they reach a sunny slope, carpeted with fresh, untrodden snow, where the Alpine peaks shelter them from the wind and the sun shines upon their brown bodies. There, in a sun-trap, they set up their desks and stools and work at their lessons, under the direction of a teacher as naked and as brown as themselves, while their bodies acquire vigour from the sun.

Lessons over, they enjoy themselves as only healthy children can. Toboggans and skis are got ready, and the slopes ring with care-free laughter. There are plenty of tumbles, but the children are so immune from the cold that they do not even trouble to brush the snow from their bodies. They are living a natural life, that of the perfectly fit. Often at the school one sees amusing contrasts when visitors stand amazed at the sight of these brown bodies that do not feel the cold.

It is all the more astounding when we remember that these same children, only a few weeks before, arrived at Dr Rollier's hospital as bed-ridden invalids. Some suffered from diseased hips and legs; others had terrible lumps in their backs. Yet there they are, with limbs healed and backs straightened, playing like a bunch of athletes.

How has the marvellous transformation been effected? The answer is—through the sun and Dr Rollier. For months, perhaps, those children have lain in their beds while the sun's rays have bathed their bodies and healed them. Those rays of sunshine, which mankind neglected for centuries, are the greatest of all germicides; they destroy the disease germs which cause surgical tuberculosis (though, unhappily, not the germs of pulmonary tuberculosis) if the doses are administered with care and knowledge.

In those last four words lies the clue to all the patient work that has brought success to Dr Rollier's hospital and fame to its founder. For if it is used in haphazard fashion sunlight can be a terrible destroyer instead of a gentle healer. Nowhere is this recognized more than at Leysin, for Dr Rollier and his assistants, whose only cure is their use of the sun, know full well how deadly that sun can be. To expose a diseased body to the full rays of the sun in summer would be fatal. The sunlight has to be administered in small doses, which are gradually strengthened as the body becomes accustomed to the changed conditions.

The method of treatment was described to us by some one who has recently visited Leysin. He said:

> When a child goes to Leysin one foot will be exposed to the sun for five minutes; the next day both feet will be exposed. Most carefully the child is watched, to see how the body is reacting to the sun's rays, and perhaps a week later one whole leg will be exposed, then the other. So it goes on until the whole body is acclimatized and can stand the sun's rays for

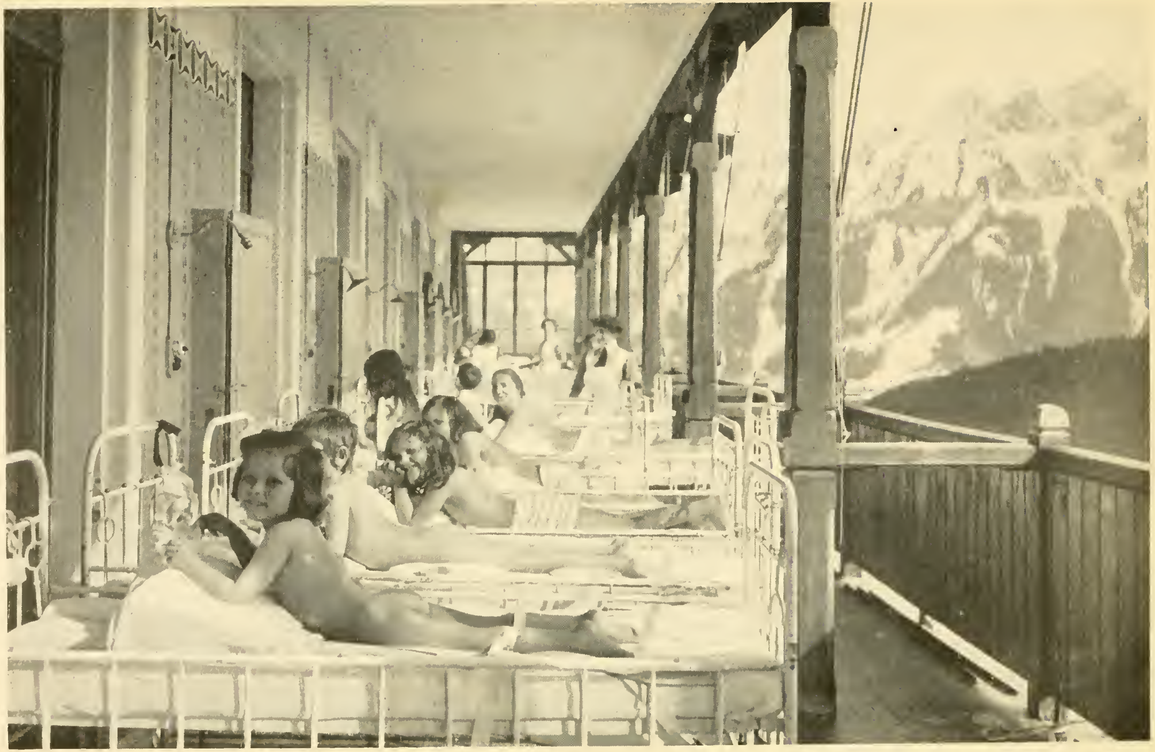
> long stretches at a time. With the cure goes a rational diet, mainly of fruit and milk; very little meat is eaten, and it is never taken more than once a day.
>
> The sun-baths are enjoyed for so many hours a day, and then the patients rest. In summer, when the sun is very hot, the sun-baths are taken first thing in the morning, to avoid the dangers arising from too-powerful rays. The body gets browner and browner day by day, and the muscles, instead of wasting owing to lack of use, actually develop under the healing rays of the sun. After a few months some of the children are so well developed that they look as though they have been taking a course of physical exercise instead of lying in bed for week after week.

Twenty-six years ago Dr Rollier built his first *solarium,* or sun-bath, on the roof of an old *chalet* in Leysin. Now great palaces, designed on the most scientific lines, are dotted about the mountain-side. The rooms have double doors, there are polished floors, hygienic and germ-free, theatres, cinemas, and restaurants—the latter conducted by men who know how to provide a healthy diet that will satisfy the enormous appetites created by the sun.

Two sections of this remarkable hospital are maintained by the Swiss Government for the treatment of its soldiers. Other sections are for the use of poor persons.

All the patients breathe pure air, free from smoke, are given fresh food, and enjoy the benefits of living at a high altitude. But without the sun all these things would not be sufficient to cure them. If ever there was a place in the sun, it is Leysin, for the sun shines there summer and winter. Often in December, when the snow is a couple of feet thick on the ground, the sun temperature touches 105 degrees. To that fact visitors owe the queer sight of youngsters playing in the snow, and at the same time wearing sun-helmets to protect themselves from sunstroke.

No doctor in the world has achieved a more wonderful work than Rollier, who laboured for years in a corner of a



‘DR SUN’ AT WORK CURING DISEASE ON A BALCONY OF DR ROLLIER’S CLINIC

little country before even his own profession heard of him. In 1913 he came to a great International Medical Conference in London, and read a paper on his work, showing lantern slides. There were only twenty doctors present to listen to him, and he does not think that any of them were English. This country was still in the Dark Ages—we were still neglecting the sunlight that was free to all, and few stopped to listen to the man who was making diseased bodies whole with the aid of the sun's rays.

In 1921 another International Congress, held in London, discussed tuberculosis. There was nothing on its programme connected with heliotherapy, or curing by the sun. But the medical profession was awakening nevertheless to the power of this greatest of all healers.

The cures worked by the sun at Leysin are now having a profound influence upon medical treatment throughout the world. Centres are being opened in England where the methods of Dr Rollier are being practised by those who have been to Leysin and studied his work. Perhaps the nearest approach to the hospital at Leysin is to be found in those Homes for Crippled Children founded by Sir William Treloar at Alton and Hayling Island. For we know that while high altitudes are best for the treatment of many diseases, it is not necessary to go to a height of 5000 feet in order to use the curative powers of the sun. It will help to conquer disease anywhere in this country where the curse of smoke can be eliminated, so that the ultra-violet rays can reach the invalid.

CHAPTER XIX

MOSQUITOES AND MALARIA

How Sir Ronald Ross Conquered an Enemy of Man

THE history of Science is a record of attempts made by devoted men and women to wrest from nature secrets which enable us to save life or to develop life more fully day by day. If the seeker after truth succeeds in adding something to the sum total of human knowledge, then sooner or later his work is recognized. If he fails, his work remains unknown to the world, and others carry on the search.

Often the margin that divides success from failure is as narrow as a knife-edge. A few minutes' extra work when the body is already tired beyond endurance and the brain cries " It is useless " may result in a discovery that will save countless human lives. Sometimes the discovery comes like a flash of lightning. More often, as this volume reveals, it is the reward of infinite patience, of sheer dogged persistence which takes no thought of time or difficulties or sacrifices.

To patience of that order the world owes the greatest medical discovery of the past fifty years—the discovery that malaria, dread scourge of the tropics, is ' carried ' by mosquitoes. Apparently simple, yet a discovery that has revolutionized the whole study of tropical medicine, and made inhabitable vast tracts of the earth's surface where formerly men died or were incapacitated in their tens of thousands. None knew how this terrible disease was spread, until the secret was revealed by two British doctors, who will always be honoured as benefactors of the human race.

To solve the problem we have referred to, Sir Ronald Ross toiled for years in India, being encouraged by Sir Patrick Manson at home. A dozen times he nearly abandoned hope of finding the evidence that he sought. His eyesight nearly failed under the strain. He became so weary that when he found his first clue he did not realize that he was on the verge of success after years of failure.

The story of how this remarkable man, whose services to humanity have even now not received just recompense from those enriched by his work, finally detected the means by which the germs of malaria are spread is one of the most romantic in the whole history of scientific research. Had he failed, millions now living in Asia, Africa, and America would be dead.

Of all tropical diseases the most common is malarial fever. It causes roughly one-third of all the attendances at hospitals in the tropics, and about one-third of the entire population in many hot countries suffers from it every year. Although only about one case in several hundreds proves fatal, yet the disease is so prevalent that the total number of deaths due to it is colossal. It has been officially estimated that in India alone something like 1,300,000 deaths are caused by it in an average year. It has affected Europe as far north as Holland and England. In Greece and around Rome the disease was until recently a curse. Over a vast part of the earth's surface malaria remains a plague which threatens at every turn all who live within the region affected.

For years scientists and doctors sought the secret of how it was spread. Some declared it to be caused by the night air, others that it came from infected water. Both theories were to be disproved.

In demonstrating to the world how malaria was spread, and thus how it could be fought, Manson and Ross defeated the tiny flying insect which until the beginning of the twentieth century was the most dreaded enemy of the British Empire—an enemy before which army, navy, and doctors were powerless.

Sir Patrick Manson was a Scottish doctor, born near Aberdeen, who in 1866 went out to become medical officer at a Chinese hospital in Formosa. There he studied elephantiasis, the strange disease which causes legs and arms, or other parts of the body, to assume monstrous proportions. And there he was first brought into contact with malaria at close quarters.

A theory then generally held was that elephantiasis, a tropical disease like malaria, was caused by the night air of marshes. Manson began his investigations, and came to the conclusion that the presence in human blood of a parasite called the filaria worm probably had some connexion with the disease. But the discovery only raised a greater problem. How did the filaria worm get into the blood? The worm could neither walk nor fly. A possibility was that it was sucked up by something that fed upon human blood, then released again into the bodies of previously uninfected persons.

The evidence pointed to the mosquito, which in biting a person infected with the germs of elephantiasis, and then passing on to uninfected persons, might well spread the disease. To test this theory, Manson examined the blood of some of his native helpers at the hospital. Finding one who was heavily infected, he induced him to sleep in a room containing mosquitoes and to let them bite him.

The next morning Manson collected the insects, gorged with the blood of the infected boy. He dissected them and examined them under a microscope. They were all infected with live filaria worms. Thus was it discovered that the mosquito was the carrier of the germ which caused elephantiasis.

Manson's discovery set certain men thinking. If the mosquito carried the parasite of one disease from person to person, might it not also spread malaria? A French doctor working in Algeria, named Laveran, definitely suggested that the mosquito might spread malaria. But the medical world in general was in no hurry to give up its theories on the subject. Manson retired from practice in China and came to live in England.

Nothing further was done for some years.

Then in 1894 Major Ronald Ross, of the Indian Medical Service, a doctor who had long been interested in the study of malaria and other tropical diseases, returned home on leave, and while in London called upon Manson. The hour for the final onslaught had struck. Manson explained his theories to Ross, who resolved, upon his return to India, to begin at once the experiments which have led to such triumphant results.

Thus began one of the most famous partnerships in the history of research, a partnership between two devoted servants of humanity, one in London and the other in India, who laboured for four years, inspiring and encouraging each other when doubts assailed them.

Back in India, Major Ronald Ross set to work in earnest. He contrived to have mosquitoes suck up blood full of the parasites of malaria. If mosquitoes were actually the carriers of the disease, then the parasites would be found, alive, within their bodies. But although he dissected hundreds of insects, Ross could not find what he was seeking. Actually, he was then trying to infect the wrong type of mosquito, for only one variety, and only the female of that variety, is able to suck up and develop the germs.

Month after month Ross toiled away. Experiment succeeded experiment without success.

Manson still believed that it would be found that human beings contracted malaria from mosquitoes through drinking water infected by the insects after they had sucked up blood containing the germs. Ross disproved this, and found the real solution, but not until he had wasted valuable time in testing Manson's original theory.

In his *Memoirs* Sir Ronald Ross relates how he tried to establish the truth or otherwise of the infected-water theory by taking four mosquitoes which had fed upon a malarial victim and placing them in two bottles with a little water. The bottles were kept in a cool place for a week, at the end of which the mosquitoes were dead. In addition to the bodies of the infected mosquitoes, the bottles contained grubs, showing that the eggs laid by the insects had been hatched.

Now Ross made his test. After removing the bodies of the mosquitoes, but not the grubs, he gave the contents of the bottles to certain natives who volunteered, after a full explanation of the experiment had been made to them, to drink the water. " I think myself justified in making this experiment," wrote Ross, " because of the vast importance a positive result would have and because I have a specific in quinine always at hand."

The result of the experiment was odd. One man developed an illness which at first seemed like malaria, but when his blood was examined no malarial parasites were found. Two other men who drank the infected water remained quite well.

Further experiments with infected water yielded negative results. In fact, that first case of intermittent fever, which was a coincidence, was the only case in which any after-effects followed the drinking of water exposed to infected insects.

Eventually Ross abandoned Manson's theory, so far as the means of infection was concerned, and began to search for other means by which the parasites within the mosquito might enter the blood of human beings—the search which was to end in his brilliant discovery.

After many months the strain of the work in a torrid climate began to tell upon Ross. He writes of this period in his *Memoirs* (Murray, London, 1923):

> At first I toiled comfortably, but as failure followed failure, I became exasperated and worked until I could hardly see my way home late in the afternoons. Well do I remember that dark, hot little office in the hospital at Begumpett, with the necessary gleam of light coming in from under the eaves of the veranda. The screws of my microscope were rusted with sweat from my forehead and hands, and its last remaining eye-piece was cracked.

By now he had begun to suspect that the mosquito he sought was a type which eluded him. One morning a 'mosquito-man,' one of the three who collected the insects for him, produced some larvæ which hatched into brown mosquitoes with three black bars on their wings. These proved to be dapple-winged mosquitoes of a type which Ross had not worked with before.

They were allowed to bite a malarial patient in the hospital, and later some were dissected. Again no germs of malaria were found. That was on August 16th, 1897, in Secunderabad. Ross secured more specimens of the dappled-winged brown mosquito during the next few days.

Thus the story comes to August 20th, 1897, the anniversary of which Sir Ronald Ross still calls Mosquito Day. The first few mosquitoes placed under the microscope revealed nothing. Then Ross came to one of the last of the batch which had been allowed to feed upon the malarial patient on the 16th. His eyes were already feeling the strain, but carefully, methodically, he searched through the tissues of that tiny winged creature. Again nothing. At last only the stomach of the insect remained to be examined. That meant half an hour's work, and already he was tired out. Moreover, he had examined the stomachs of thousands of mosquitoes without finding any trace of the germ.

Tired as he was, he began to work again, but a kindly fate must have watched over Ross that day. What followed may best be told in his own words:

> I had scarcely commenced the search again when I saw a clear and almost perfectly circular outline before me of about twelve microns in diameter. The outline was much too sharp, the cell too small, to be an ordinary stomach-cell of a mosquito. I looked a little further. Here was another and another exactly similar cell. I now focused the lens carefully on one of these, and found that it contained granules of some black substances, exactly like the pigment of the parasites of malaria. I counted altogether twelve of these cells in the insect, but was so tired out with the work and had so often been disappointed before that I did not at the moment recognize the value of the observation. After mounting the preparation, I went home and slept for nearly an hour. On waking, my first thought was that the problem was solved, and so it was.

Ross had discovered that the germs of malaria were sucked by certain mosquitoes from the body of an infected human being, and developed in the stomach-tissue of the insect. He had made one of the greatest medical discoveries, saved millions of lives, and yet he did not appreciate what it all meant until he had slept! That incident reveals how utterly weary he was, in mind and body, at the end of months of failure.

The next day Ross dissected the last survivor of the same batch of mosquitoes. Within its stomach he found similar cells—only larger! That was conclusive. The cells were parasites, and they not only lived, but grew within the mosquito. The discovery was really two discoveries, and each was of vital importance. As Ross wrote afterward:

> We had to discover two unknown quantities simultaneously —the kind of mosquito which carries the parasite, and the form

> and position of the parasite within it. By an extremely lucky observation I had now discovered both the unknown quantities at the same moment. The mosquito was the *Anopheles*, and the parasite lives in or on its gastric wall and can be recognized at once by the characteristic pigment. All the work on the subject which has been done since then by me and others during the last thirty years has been mere child's play which anyone could do after the clue was once obtained.

In his great joy at the prospects opened up by the discovery Ross composed these verses to commemorate the day:

This day relenting God
Hath placed within my hand
A wondrous thing; and God
Be praised. At His command,

Seeking His secret deeds
With tears and toiling breath,
I find thy cunning seeds,
O million-murdering Death !

I know this little thing
A myriad men will save.
O Death, where is thy sting?
Thy victory, O Grave?

The key had been found, but much more remained to be done. Ross had studied the germs five days after they entered the mosquito. But what happened afterward? How did the mosquitoes infect human beings, and possibly each other? These questions had to be answered in order to place in the hands of doctors a means of fighting the scourge.

Unfortunately, at this point in his investigations Ross was ordered to report to headquarters in Bombay for military duty, and for some months no further progress was made. Ross wrote fully to Manson, however, sending him slides with specimens of the malaria-bearing mosquito.

Then friends in London interceded with the India Office on behalf of Ross, and in January 1898 he was placed on special duty for six months to enable him to take up again his malaria research work, now at so promising a stage.

He went to Calcutta, where human malaria is scarce, and there he settled down to work out with bird malaria the complete cycle of infection.

By March Ross had found the species of mosquito capable of carrying the malaria parasite of birds, and within a few more weeks he had traced step by step the parasite's development from the moment when it entered the mosquito until the moment it was found in the body of the infected bird. In the course of these experiments Ross gave malaria to twenty-three out of twenty-eight captive birds, none of which could have been infected by any means save the mosquitoes which were placed under the nets of their cages.

At last Ross knew just how malarial fever was spread; the sequence of events had been explored from beginning to end. On March 21st, 1898, Ross wrote home to Manson:

> My wish is that you were here to share with me the pleasure which I have experienced yesterday and to-day in seeing your induction verified step by step. Such pleasure comes to but few men, I fancy, though you must have felt it in regard to filaria [elephantiasis]. I am producing pigmented cells *ad libitum* by feeding grey mosquitoes on larks infected with proteosoma. This, of course, means the solution of the malaria problem.

When the news of this further success reached London the British Medical Association was about to hold its annual meeting at Edinburgh. It was at this meeting, in July 1898, that Sir Patrick Manson announced to the medical world the discoveries which Ross had made, and he showed for the first time the slides he had received from India. The meeting "unanimously passed a resolution sending Major Ross the Members' congratulations on a great and epoch-making discovery."

Ross had won, but still the last link in the chain of evidence had to be forged. Ross had carried out his experiments on birds. It was very probable that human malaria followed the same cycle. But there was as yet no absolute certainty, and could not be until the tests had been carried a step farther.

In the malarial region of Italy others seeking proof had infected human beings with malaria by means of mosquitoes, but there was also the night marsh air, the hot climate, and other possible sources of general infection. Manson decided to demonstrate the value of Ross's discovery once and for all by bringing mosquitoes infected with the malarial parasite to London, where there was no malarial fever at all, and there infecting human beings by means of the insects.

Several small cages covered with fine netting were constructed, and in these the infected mosquitoes were hurried across Europe to London. There they were allowed to bite two men who had volunteered to contract malaria in order that the last link in the chain of evidence might be forged. The first of these men was Manson's son, P. Thornburn Manson. He was exposed to the insects on August 29th, 1900, and again two days later. Anxiously Manson and his colleagues waited for the period of incubation to expire. The proof was forthcoming. Young Manson began to have fever on September 13th, and on the 17th the parasites of the disease were found in his blood.

The second volunteer, Warren, was exposed later. He too contracted malaria. This experiment helped to confirm the fact for the whole medical world. As Ross has written, "a more brilliant verification of them could not have been devised."

The process by which the parasites of the disease are first sucked into the body of the mosquito, and later injected into the blood of another person, is one of the most amazing things ever discovered about the insect world.

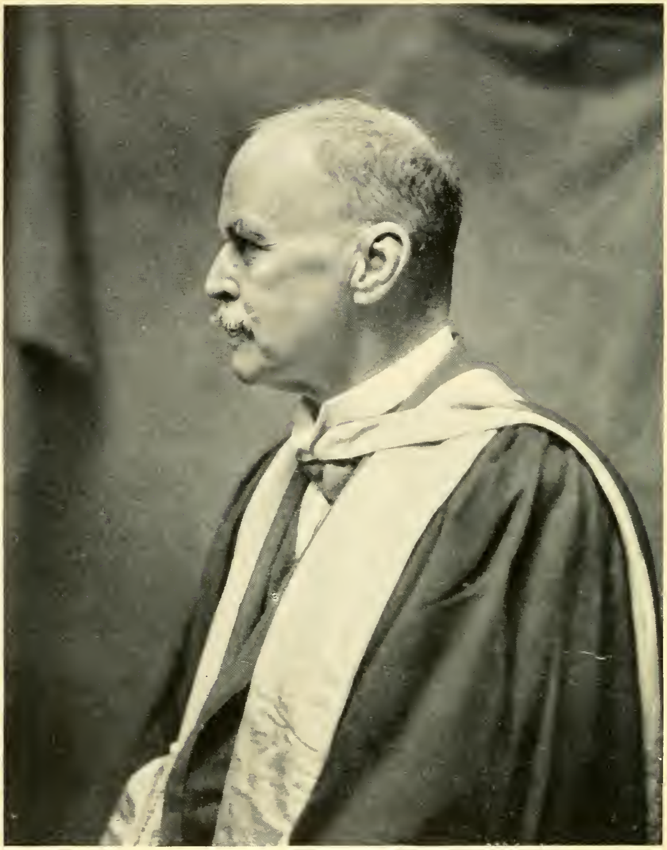
Three or four days before the female mosquito lays her eggs she settles upon a human being and gorges herself with blood. If the person she happens to bite is infected with malaria, the insect sucks up into her stomach the parasites of the disease. These parasites do not die, but are fertilized and multiply while within the mosquito. The malaria germ then undergoes a change, after which it finds its way down the walls of the insect's stomach and forms a cyst. In this cyst thousands of little pointed bodies develop, until finally the cyst bursts and these bodies find their way into the salivary glands of the insect. The germs are then ready to leave the mosquito's body, and the next time the mosquito pierces the human skin to suck blood they enter the puncture, and a few days later there is another victim of malarial fever.

All that is probably a little difficult to follow, but its being so is a further tribute to the endless patience of the man who tracked down this amazing secret of nature for the first time, by dissecting thousands of tiny insects, and who, despite many failures, thus pieced together that complete picture.

There were many ready to scoff. Even after Ross had infected birds by exposing them to malaria-carrying mosquitoes there were many who declared that he and others had "mosquitoes on the brain."

Happily Ross was content to pursue his investigations to the end, undeterred by criticism and unspoiled by praise. He believed he was on the right road. That was enough. To him is the glory of a great victory over death and disease.

Ross's discovery brought him honours, but not wealth.



COLONEL SIR RONALD ROSS, K.C.B., K.C.M.G

Photo by Haines

Like many others who have devoted their lives to research, Ross is still a poor man. For his work he was awarded in 1902 one of the greatest distinctions of its kind in the world—the Nobel Prize for Medicine. There exists in Putney an Institute of Tropical Diseases named after him, and of which he is Director-in-Chief. The medical societies of the world have paid tribute to his great work in conquering malaria.

That work still marches on. The new chapter in the battle with tropical diseases which Ross and Manson opened is not yet finished. It may be found that other deadly diseases are spread by the same winged insects. While Ross's discoveries were still recent, American scientists turned to them in the hope of discovering the cause of yellow fever, which had broken out among American troops at Havana in 1900. In mosquito-proof cages men were exposed to the soiled bedding and clothes of yellow-fever victims. They remained free of the disease. Then volunteers were called for, and a number of brave young American soldiers, knowing the risk they ran, volunteered to be bitten by mosquitoes which had fed on the blood of those already sick. All who were bitten developed the disease, and before the end of December 1900 it had been proved conclusively that just as malaria is spread by mosquitoes, so is the even more deadly yellow fever. The discovery was made by Dr Walter Reed and the other Americans who fought the epidemic, but some of the honour must also be awarded to Sir Ronald Ross and Sir Patrick Manson, whose discoveries had already pointed the way.

Sitting in the barracks at Cuba, amongst those afflicted with the disease, Dr Reed wrote to his wife at 11.50 P.M. on December 31st, 1900:

> Only ten minutes of the old century remain. Here have I been sitting, reading that most wonderful book, *La Roche on Yellow Fever*, written in 1853. Forty-seven years later it has

> been permitted to me and my assistants to lift the impenetrable veil that has surrounded the causation of this most wonderful, dreadful pest of humanity and to put it on a rational and scientific basis. The prayer that has been mine for twenty years, that I might be permitted in some way or at some time to do something to alleviate human suffering, has been granted.

Outstanding as Reed's achievement was, Ross's discovery deserves even greater praise. To it may be traced nearly all the progress made in fighting the malignant fevers of the tropics. What Ross's discovery has meant in those regions is made clear in a letter written to him by General Gorgas, of Panama Canal fame.

The letter is dated March 23rd, 1914, and in it General Gorgas says:

> Before leaving England I wish to express to you the debt of gratitude we all feel to you for the great work you have done in the field of Tropical Medicine. As you are aware, malaria was the great disease that incapacitated the working forces at Panama before our day. If we had known no more about the sanitation of malaria than the French did, I do not think we could have done any better than they did. Your discovery that the mosquito transferred the malaria parasite from man to man has enabled us at Panama to hold in check this disease, and to eradicate it entirely from most points on the Isthmus where our forces are engaged.
>
> It seems to me not extreme, therefore, to say that it was your discovery of this fact that has enabled us to build the Canal at the Isthmus of Panama.

A fine tribute, and one that was richly deserved.

When Ross went to India as a young man he found every one, even the most brilliant doctors, struggling in vain with a disease which attacked millions every year. They could mitigate its attacks with quinine, but they could not prevent them, and they did not even know where to look for the enemy. In the course of four years

Ross both discovered the enemy and showed how it could be conquered.

Those yet unborn, wrestling with other secrets of life and death, will know moments when the struggle seems hopeless. In those moments perhaps they will remember the story of Sir Ronald Ross, and find in it their inspiration.

CHAPTER XX

A MODERN ALCHEMIST

Sir Ernest Rutherford and the Lilliputians

IMAGINE an Association football as big as a room—say about fifteen feet in diameter. Now imagine an object the size of a pin's head fixed in the centre of this great ball. Around that fixed centre, whirling at dizzy speeds, imagine other bodies much smaller than the pin-head nucleus. Now imagine all this on a scale in accordance with which the football represents an object measuring about the *one-hundred-millionth of an inch* across, and you have the modern conception of the atom.

The fixed centre is called the proton, and although so small (less than one-ten-thousandth the size of the atom) it is enormously powerful, for the charge that it contains controls the electrons which are its satellites. The whole arrangement of an atom may be compared with the solar system, having a sun in the centre and planets spinning around it at various distances and in various paths. Atoms are the tiny bricks which build up matter, and the properties of an element are defined by the electric charge on the nucleus of the atom. In the case of hydrogen, lightest of all elements, this charge is sufficient to hold only one satellite or electron, and by going up the scale you reach at the top uranium, the nucleus of which is sufficiently powerful to control no fewer than ninety-two electrons.

We have explained that an atom is so small that one hundred million could be placed side by side in the space of an inch, but even that statement gives very little idea of their extreme minuteness. Let us put it this way.

Supposing that in an ordinary electric light bulb a hole could be punched small enough to let in a million atoms of oxygen a minute, how long do you think it would take to fill the bulb? The answer is one hundred million years!

Lord Kelvin has given us another calculation which makes us realize the minuteness of the atom. Write down twenty and follow it by eighteen noughts. This gives the number of molecules (not atoms) which occupy one cubic centimetre at freezing-point. Since a cubic centimetre represents about one-third the contents of an ordinary thimble, it follows that a thimble will hold 60,000,000,000,000,000,000 molecules, each of which, in the case of hydrogen, consists of two atoms. The total weight of this almost incredible number of molecules is about the one-seven-hundredth part of a grain.

In order to begin his investigations concerning the atom Faraday had gold beaten into leaf which was only one-millionth of an inch thick. Yet this film, so fine as to be quite transparent, was estimated to contain between ten and fifty layers of molecules, and a molecule, remember, is built up of several atoms. It was necessary to get something thinner even than the fragile gold-leaf, and this was done by putting a drop of oil on to a large basin of water. The film thus formed was about a millionth of an inch thick. At first this film showed the marvellous variety of prismatic colours which you may see upon a wet road where oil from a car has been spilled, but as the film grew thinner a black spot appeared, the blackness indicating that the film was then too thin to reflect any light. This black portion of the film provided material from which the maximum size of atoms could be calculated.

Even so, no one has ever seen an atom, and probably no human eye ever will, and that being so it seems incredible that we know so much about these complicated little bodies. For our knowledge we are indebted to the long and careful experiments of men, such as Sir Ernest

Rutherford, who have spent their lives in difficult and patient investigation.

The atomic theory was first given to the world by Dalton more than a century ago; the electron was discovered by Professor J. J. Thomson in 1897; but it has remained for Sir Ernest Rutherford, working with Dr Geiger and others, actually to break up an atom and to put forward the theory of the proton or charged centre.

To break up an object so small that you cannot see it seems rather a tall order, and the more so when it is an object hitherto believed to be indivisible. The very word 'atom' implies something that cannot be divided. Sir Ernest knew that whatever weapon he employed would have to be very powerful. His thoughts turned to radium, the strange element on which he had already done a great deal of work since its discovery by the Curies.

Radium, as you know, is so called because it is radioactive. It is unstable, and has the peculiar property of breaking up and constantly discharging extremely small particles. Sir Ernest came to the conclusion that the most powerful projectiles which he could possibly employ were the so-called *alpha*-particles which radium is always discharging.

Some readers may have seen the living picture of radium rays which was originally taken in the Cavendish Laboratory at Cambridge. The room is darkened, and on the screen appears a snow-storm of tiny sparks of light which come and go like snow-flakes falling on the surface of a stream. These travel at the almost incredible speed of *eighty thousand miles a second.*

The first experiment Sir Ernest made consisted of driving numbers of these *alpha*-particles into a vessel filled with nitrogen gas. This was shooting at random, and he could not know in advance whether any of his tiny bullets would do the job he proposed for them. But they did. He found that one in about ten million collided

SIR ERNEST RUTHERFORD

Photo by Elliott and Fry

head-on with a nitrogen atom, and that the result of such a collision was to break up the structure of the atom to some extent and to bring about what the alchemists of old were always striving for—a transmutation. In simpler words, part of the nitrogen was actually turned into hydrogen.

Sir Ernest continued his experiments, working upon fluorine, sodium, aluminium, and phosphorus, and in every case the result was the same. In all, twelve of the lighter elements were tested, and in every case a hydrogen nucleus or proton was driven out at great speed.

Having read so far, you will doubtless wish to know how Sir Ernest and his assistants could possibly satisfy themselves about the results stated. The answer can be given in one word—rather long, yet very familiar—spinthariscope. The spinthariscope, originally invented purely as a scientific instrument, has become a scientific toy, and very many people have seen the brilliant little flashes which occur when a morsel of radium is allowed to bombard the screen of zinc sulphide. In Sir Ernest's experiments each proton liberated could be detected by its flash when it struck the screen.

Since these first experiments, which were made at Manchester University, other methods of detecting these minute particles have been perfected. Each as it enters a chamber can be made to record itself. It can be made to ring a bell, to click on a telephone receiver, or to deflect an instrument.

It may be mentioned here that by the use of a vacuum tube radio amplifier, which magnifies the sound a hundred thousandfold, the rain-like blows of many electrons on the plate of a tube have been heard, making a sound like a great waterfall in the distance. This strange effect was achieved in America by Dr A. W. Hall and Dr N. H. Williams, of Michigan University.

Sir Ernest has widespread interests, as his speeches and lectures indicate. Each year the Royal Society holds an anniversary dinner, and Sir Ernest was one of the principal speakers at the dinner of 1929. He said:

> I am sure that if we could look back a hundred years from now we should see that this was the Golden Age of improvement in matters of communication. . . . If this is a time of great development in practical science it has been inevitably followed by great changes in the body politic. The motor-car, the flying-machine, and wireless have probably had a greater effect on the world than any previous discoveries. Of one thing I am certain—that the banishment of distance—and we can communicate from one end of the world to the other in one-fifteenth of a second—has inevitably brought the world together, and we may be sure that the effect of that will be to bring the whole peoples of the world into closer contact.

The value of the earlier discoveries in radio-activity has already been proved, and in radium and radium emanation there has been secured a means of fighting one of man's greatest scourges, cancer. The question now is how far mankind will benefit by the breaking up of the atom. If some means could be devised for releasing and exploiting the internal energy of the atom, we should have a source of power such as was never even dreamed of before. While Sir Ernest himself has never made any prophecy as to the likelihood of man's being able to break up the atom and employ atomic energy, this is a favourite subject for writers of scientific fiction.

Some years ago Mr Wells in his *World Set Free* gave a most interesting forecast of the progress of invention during the next half-century. He tells how in 1933 gold was produced from bismuth. " In this year was solved the problem of inducing radio-activity in the heavier metals and so tapping the internal energy of atoms." His hero, Holsten,

> set up atomic disintegration in minute particles of bismuth,

> which exploded with great violence into a heavy gas of extreme radio-activity, which disintegrated in its turn in the course of another seven days, and it was only after another year's work that he was able to show that the last result of this rapid release of energy was gold.

He goes on to the year 1953, when the first Holsten-Roberts engine brought induced radio-activity into the sphere of industrial production, and began to replace the steam engine. The result was an age of astonishing prosperity, but of course the coal-mines and oil-wells were doomed, gold depreciated, and in the end the results were terrible as well as splendid.

Scientists do not deny that man may eventually find means for utilizing atomic energy, but that day is still a very long way off. The difficulties in the way are enormous, and so far Science is only touching the fringes of the subject. Yet there is certainly no need for such panic as was caused when in 1924 Dr T. F. Wall, of Sheffield University, announced that he was endeavouring to split up the atom of copper. Many of his correspondents seemed to be under the impression that the result of splitting an atom would be the destruction of the world we live in. One wrote:

> DEAR SIR,
>
> Please don't blow up the atom. I am terrified. Please—please leave things alone.
>
> ONE WHO IS FRIGHTENED

Another letter ran as follows:

> Having read to-day of your wonderful invention for blowing up the world next Wednesday, kindly make it Thursday or next Sunday, after we have had our half-holiday and drawn our September salaries. Trusting this will meet your kind approval and wishing you every success,
>
> A BELIEVER IN INVENTIONS

A father was angry. He wrote:

> I regret to see you are determined to carry out your experiment. Perhaps if you were a married man with children and not so callous you would not be so keen on the possible destruction of the human race. Oh! you must be hard to have no pity for those with loved ones. May God curse you if you carry out your experiment!

The world remained uninjured, but if experiments such as these do in the long run lead to the industrial use of atomic energy human life will surely be revolutionized, for there is enough energy in half a pound of lead—if it could be released—to drive a fifty-thousand-ton steamer across the Atlantic or to carry a flying-machine round the world. Dr Aston says:

> If we could transmute hydrogen into helium we should produce energy in quantities which, for any sensible amount of matter, are prodigious beyond the dreams of fiction. I calculate that for one gram-atom of hydrogen (the quantity in a quarter of an ounce of water) the energy exceeds a quarter of a million horse-power hours. So in a tumbler of water lies enough power to drive the *Mauretania*. The reason why there is so much power in the atom is that while the dimensions of its nucleus are almost inconceivably small, yet the forces binding together its component parts are gigantic and to be measured in millions of volts.

The latest attempt to split the atom is being made by Dr Lange and two other German scientists at the top of Monte Generoso, on the shores of Lake Lugano. Since it would cost millions of marks to obtain the necessary tension in a laboratory, Dr Lange has hit on the idea of harnessing lightning, and has constructed a station with a cable earthed at one end and insulated at the other by a double chain of one hundred and sixty steatite insulators weighing together five thousand pounds.

"Heaven forbid," he says, "that lightning should *strike* the cable. Any electrical disturbance in the district will be sufficient for our purpose."

After nine years in Canada Professor Rutherford came back to England, to a new post at Manchester University. He was already a Fellow of the Royal Society, and in 1908 was awarded the valuable Nobel Prize for his researches into the disintegration of elements and into radio-active substances. Then he came to Cambridge as head of the Cavendish Laboratory, which is to-day the very heart and centre of Physical Research.

The Cambridge Science Laboratories are built on land which the University purchased in 1762 for a Botanical Garden. In 1870 the Duke of Devonshire offered the University six thousand three hundred pounds for building a laboratory, and the work was begun at once. In those days, little more than half a century ago, Science was so little thought of that at first there were only twenty students. Even in 1885 there were only ninety students, and the ignorance of some of these early students was so astounding that we are tempted to end this chapter with a few examples of it.

At the first M.B. examination two papers were given on elementary physics. Being asked the use of a thermometer, one student wrote that it was "an instrument for deciding the specific gravity of water." Another was shown a compass needle mounted on a graduated circle and asked its use. He at once declared that it was used for detecting the latitude and longitude of any place.

"What!" exclaimed the scandalized examiner. "Can you detect the latitude and longitude of any place by the use of this compass?"

"No, sir," replied the ingenious youth, "but you can."

A third student was given a spirit-level and asked to say which end of the examination table was the higher. He stared hard at the instrument, and noticed that the bubble had moved, though the table apparently had not. Filled with indignation he looked up at the examiner.

" Why, the bally thing is cock-eyed ! " he declared with scorn.

CHAPTER XXI

FORECASTING BRITISH WEATHER

Dr G. C. Simpson and the Meteorological Office

WE have all heard of the Clerk of the Weather—that mythical official who is supposed to look into the future in order to tell us what to-morrow's weather will be like.

Nearly every one in Great Britain reads the weather forecast in the newspapers before making plans for the day, or listens to the wireless forecast in the evening.

Few people know, however, that that nightly forecast is based upon meteorological observations made not only in this country, but all over Europe, at 6 P.M. Greenwich mean time on the same evening. Between that time and the broadcast the reports have been dispatched by wireless to the Meteorological Office at the Air Ministry, collected there, ' plotted ' on weather charts, and discussed by the experts, who thus foretell what sort of weather the next day will bring.

This modern triumph of speed is made possible by the fact that there is not one Clerk of the Weather, but thousands.

The observations received each day from abroad cover an area extending from within the Polar Circle to North Africa, and from Russia to the Azores. Within this wide area weather-readings are taken four times a day, collected by central stations, and immediately broadcast by powerful wireless stations to all others. Also, a report is received each day from the United States, giving observations from seventy-five stations in North America, including a number of weather stations in Canada.

For forecasting purposes information concerning weather in the Atlantic Ocean is of vital importance to this country, and a special system of reports from merchant ships has therefore been organized between England and America. A number of liners co-operate in this work.

Even more important, if our weather reports are to be as accurate as Science and organization can make them, are the 'local' reports collected by observers at more than sixty weather stations in all parts of the British Isles. These observers are men and women in all walks of life; sixteen of the stations are manned by Meteorological Office staff, the remainder being maintained by voluntary observers—lighthouse-keepers, farmers, newspaper reporters, and others—who have been trained to take accurate readings of the weather signs at a specified hour each day, and to send these in code, together with details of rainfall, sunshine, winds, temperature, and pressure, to the Meteorological Office. These observers help both to make our weather forecasts accurate and to record the history of the British climate. They have been trained to look at the skies with a scientific eye. After making their observations they go to the nearest post-office and send off a mysterious-looking telegram to Adastral House, Kingsway, which is the headquarters of the Meteorological Office.

There are also the stations, about three hundred in all, which take observations a number of times daily, and report weekly or monthly to the Meteorological Office. The health resorts, too, maintain their own meteorological stations, and every evening report their weather for the day, giving temperature and duration of sunshine.

Rainfall is measured at nearly 5000 stations, distributed over the British Isles, and the statistics collected are of very great value in connexion with water-power schemes and water-supply generally.

Even this network of weather observers does not

DR G. C. SIMPSON

Photo by Elliott and Fry

complete the wonderful organization through which come our weather forecasts, for the Meteorological Office also maintains five first-class observatories at strategic points in the country. These observatories are at Kew, Eskdalemuir, Aberdeen, Lerwick, and Valentia (all names which figure frequently in weather news), and here further meteorological and other observations are taken by experts, with the aid of self-recording instruments.

Co-ordinating the work of all these outposts is the Meteorological Office itself, with its staff of scientists whose names are known to meteorologists the world over.

The Director of the Department is Dr G. C. Simpson, C.B., F.R.S., who has carried out meteorological research in places as far apart as Lapland, Egypt, India, and the Antarctic. In the last-named region he served with Captain Scott's expedition, and secured valuable information by the use of balloons.

Born in Derby, and trained at Manchester, Dr Simpson has done work which has greatly increased our knowledge of meteorological phenomena. The results of his research into radiation are too technical to be explained here, but they have changed accepted views concerning the four great Ice Ages of the world, and the theories which he has advanced as the result of experiments in connexion with atmospheric electricity and lightning discharges have done much to stimulate further research into what we may call the science of thunderstorms.

A speaker on the occasion when Dr Simpson was presented with the Symons Memorial Medal for 1930 declared:

> His studies indicate that during a thunderstorm non-conducting clouds are floating within a conducting atmosphere, thus completely reversing accepted ideas. As to the origin of electrical energy during a thunderstorm, he finds that the breaking-drop theory could account for the generation of the supply.

> When pure water splashes against a solid obstacle, electrification ensues, and when a drop of water is broken up in the air without striking anything, a similar separation of positive and negative electricities occurs. In a thunderstorm there is a region in which every time a raindrop breaks the water of which it is composed receives a positive charge. A corresponding negative charge is given to the air and is absorbed by cloud particles which are being carried upward. The rain which falls when the air-currents are vertical is thus positively charged, while at a distance from this region it is negatively charged.

The ceaseless search for new knowledge, of course, is necessarily subsidiary to the practical aspects of the Meteorological Office's work. Dr Simpson and his staff know almost all that there is to know about that inexhaustible topic the British climate. Ask them what the weather was like at Birmingham at 2.30 on September 14th, 1901, and they can tell you. Or ask them to tell you which is the warmest week of the average year at Blackpool. They can tell you that also.

Not long ago a Bill for stabilizing Easter was discussed in Parliament, and it was suggested then that the weather at Easter as it would be fixed by the Bill would not be as good for holiday-makers as the weather of the present movable Easter. At the request of the Home Secretary the question was referred to the Meteorological Office. The weather of the Easter week-ends during the past hundred years was compared with that of the week-ends on which Easter would have fallen if the Bill had been in operation. The result of this investigation indicated that as regards rainfall London would neither have gained nor lost anything by stabilizing the date. On the other hand, as regards sunshine and temperature, the fixed Easter —coming later than do some Easters under the present system of fixing dates—would have been an improvement.

Here is another question which the Meteorological Office helped to settle. When work began on the erection of overhead transmission cables in connexion with the new scheme of national electrification, facts were required regarding the maximum pressure of wind likely to be experienced in various parts of the country. It was of vital importance that the towers supporting the cables charged with high-power electrical current should not be blown down. The Meteorological Office searched through its records and supplied the facts.

The weather information in the Admiralty handbooks is supplied by Dr Simpson's Department, with the aid of a fleet of five hundred ships which take meteorological observations on the high seas. Information concerning weather conditions is constantly being supplied to the Army and Navy and Air Force.

It was known, for example, that the firing of certain heavy guns at Shoeburyness was liable to cause damage in surrounding towns, chiefly in Southend. The assistance of the Meteorological Office was asked for, and an investigation revealed that the intensity of sound is dependent upon atmospheric conditions. In certain circumstances firing can take place with little disturbance in Southend, while on other occasions the disturbance is intensified to the point of danger. The meteorologist in charge at Shoeburyness now informs the Army officials when conditions are suitable for firing, and since this procedure has been adopted cause for complaint has almost entirely ceased.

When the Empire Marketing Board required regular information concerning the rainfall at a number of places in the Mediterranean, they went to Dr Simpson's Department for the data. An entomologist in Tanganyika who desired information concerning the structure of wind gusts in relation to the flight of birds and insects had his inquiry answered. When the Colonial Office wanted weather information affecting the whaling industry in the South Atlantic they asked for it at Adastral House, and did not ask in vain. And in addition to all this special work—and much more not mentioned here—the Meteorological Office supplies to the public special forecasts and reports at the rate of over 4000 a year.

Now all this work depends upon two things—accurate records concerning weather in all parts of the country and dating back for many years, and accurate daily observation.

We have shown how these daily records are gathered from all points of the compass. The recording and indexing of these masses of figures is in itself a science demanding the services of experts. Every fact from every observer and foreign station must be duly noted in the appropriate records, for a century hence some big issue may hang on the work which is being done at Adastral House to-day, just as we in our day owe much of our knowledge and the value of our records to the careful work of bygone generations.

From this brief record of the work of the Meteorological Office it will be seen that the recording of the weather is becoming more and more important, not only to holiday-makers, but to all who travel by land, sea, or air. The Air Ministry has now instituted an annual training-class for weather observers at Kew Observatory, London. Here those who assist in collecting daily statistics about the British climate are taught to handle the delicate instruments used to register exact information concerning sunshine, rain, fog, temperatures, and other factors.

The ordinary thermometers with which every observer is equipped are like those we are all familiar with, but bigger. Special thermometers are used to record the highest and lowest temperatures of the day. In the thermometer which records the highest temperature of the day a small length of mercury detaches itself from the main column when the temperature falls from its highest value, and stops in that position, thus providing a record of the highest temperature. The thermometer which records the lowest temperature of the night is usually filled with spirit instead of mercury, and has a small metal index immersed in the spirit. As the temperature falls the index is carried down by the spirit, but when the temperature rises again the spirit flows past the index, leaving it to register the lowest temperature attained.

The instrument which measures rainfall consists of a copper cylinder four to six inches high, with a funnel-shaped bottom, fitting into the top of a ' splayed ' copper vessel firmly fixed in the ground. A glass vessel is placed inside the base below the funnel to catch the rain-water. The observer takes off the funnel and pours the water from the glass vessel into a measuring-glass, on which he reads the amount of rainfall since the last observation, in inches or millimetres. The result is recorded in the observer's register, and in the case of a station which reports by telegraphy it is included in the message to Adastral House.

Sunshine is measured by burning. A clear glass ball is partly encircled by a metal belt at a distance of about an inch. Fitted into this belt is a blue card marked off in sections by white lines, each line representing one hour. The sun's rays are caught by the ball and focused on to the blue card, where they trace a thin burnt line into it. Thus, if there are four hours of continuous sunshine, a line is burned across four sections of the cord. If the sun is obscured, the point of the card which would have been under the rays at that moment is unburnt.

" Visibility good," says a weather report. What does the phrase mean? At Kew Observatory one may learn. Standing on the roof, the observer takes local landmarks as guides. Thus thick fog at Kew means that a shed a few feet from the building is hidden. A near-by church is another point; the Richmond golf club-house is another. Each point has its corresponding state of visibility—

before Kew reports " visibility good " it is necessary for the observer on the roof to see clearly a distance of twelve and a half miles. A visibility of one and a quarter miles goes down in the records as mist or haze.

The atmospheric pollution in fog is measured, and so is the amount of dirt in rain.

The dirt in fog-laden air is measured by sucking the air into an instrument, inside which it passes through a piece of filter-paper, leaving tell-tale spots of dirt, which are then examined under the microscope.

Finally, wind is measured by a weather-vane which writes down its own messages. Both the direction and force of the wind are automatically recorded, for as the wind blows it moves a thin metal arm at the end of which is an inked pen-nib. This nib traces a graph line on a roll of measured paper, which is renewed daily.

Every day observers scattered over Britain are recording the weather with the aid of these instruments. A simple code has been devised for use in the transmission of weather reports to London. Thus two capital R's mean that it has rained all day. Letter *o* means an overcast sky, while *p* denotes passing showers, *b* means blue sky, not more than one-quarter covered by clouds. But a combination of letters more frequently used in the North is *c.d.m.*—meaning generally cloudy, drizzle, and mist.

It is all very simple to read about, but years of research and experiment have been needed to bring the Meteorological Office to its present pitch of efficiency. Always the experts are seeking fresh knowledge, for there are still many things to be discovered about weather. Granted the opportunity of studying the weather conditions at the Poles, weather experts may presently be able to provide long-range forecasts of summers and winters, which will be of immense assistance to agriculturists all over the world.

CHAPTER XXII

BRITAIN'S NATIONAL ELECTRICITY SCHEME

Sir John Snell Hastens the Advent of a New Age

FORTY years ago England produced and consumed two-thirds of the world's coal, produced two-thirds of the world's iron and steel and two-thirds of the world's cotton goods. At that time English coal was far cheaper than Continental or American coal, and England could therefore manufacture more cheaply than other countries.

Times have changed, and now England has lost her monopoly of cheap power. She has now to go much deeper for her coal, while the United States are producing coal more cheaply than is possible in England. In any case, the age of coal is waning, for its function is being usurped by oil and electricity.

Britain has little oil and little water-power. The water resources of the United States can supply fifty million horse-power; the resources of Canada are the same; Italy can derive at least eight million horse-power from this source; little Switzerland can derive four million horse-power from her waterfalls and torrents; but Great Britain apparently can derive from this source little more than a million horse-power.

After the War it became clear that Britain's great industrial position was threatened unless some cheap form of power could be provided, and the Government decided to carry out a great State electricity scheme. A single unified system was agreed upon, and it was wisely decided that this should be run on a commercial basis and not on Civil Service lines. It was thought that in this way the delays caused by what is commonly called 'red tape' would be avoided.

And so there came into being the Electricity Board. It was laid down that this should consist of six members selected from men of proved business capacity, with a really first-class chairman. The first duty of the Board would be to plan out a comprehensive scheme for the whole country, and the Board was authorized to borrow up to thirty-three million pounds for carrying out the work.

In 1926, when the Electricity Commission started work, there were no fewer than five hundred and seventy separate electricity undertakings in Great Britain, four hundred of which were so much behind the times that between them they provided only ten per cent. of the total output of power. The Board decided to scrap most of the existing stations, and to replace them with about one hundred and fifty stations, each provided with every appliance that modern science could suggest. These stations, a number of which are already in existence, will eventually all be connected on what is called the 'grid' system.

The difficulty associated with any electrical supply system is that the demand is not constant. In every power-station graphs of the demand are kept. Between midnight and dawn the line of supply sinks almost to zero; it rises for breakfast, and keeps low, but fairly constant, during the day. Just after sunset it rises with a tremendous sweep. Every one is turning on lights at the same moment, and there is the extra demand for street lighting, for electric signs, and for cooking the evening meal. After eleven o'clock the demand again falls rapidly. In summer, of course, the demand is not nearly so heavy as in winter.

When electricity is produced from coal, obviously you cannot damp out your furnaces. They have to go on

SIR JOHN SNELL

burning day and night, for it costs a lot to relight a cold furnace. And the bill for coal is enormous. In a station which the writer recently went over this bill amounts to thirty thousand pounds a year. When a station is a single unit the furnaces can never be extinguished nor the dynamos be allowed to cease running, but if that station is connected with another, then in slack times it is able to shut down and take its current from the other station.

This results in a very great economy in coal and labour, and the arrangement is very convenient when repairs are needed. Power can thus be provided more cheaply. At present the average price in England is sixpence a unit for lighting and a penny farthing for heating and power. When the scheme is complete, these prices should fall to twopence for lighting and a farthing for power. Then electricity will be far cheaper than oil.

There is another advantage in the national system, At present the loss of power between the station and the consumer is seventeen per cent., but with the grid system, says Sir John Snell, this will be reduced to two and a half per cent. The cables will carry current at no less than one hundred and thirty-two thousand volts, compared with a maximum in the past of sixty-six thousand volts. The various stations are being linked up by chains of latticed steel masts, sixteen feet square at the base and up to eighty feet in height, carrying the main high-tension lines.

In America voltages up to two hundred and fifty thousand are being conveyed, but for this purpose no ordinary wire is sufficient. The conductor used is a tube of copper, the centre of which is filled with oil. If overloaded, a wire heats, and eventually fuses.

It is difficult to believe that only fifty years have passed since electric lighting came into being, and that power has been carried by cable for an even shorter period. Between 1870 and 1880 Edison and Swan solved the problem of making an electric lamp suitable for domestic use. Each independently invented a filament that could be heated to incandescence in a vacuum bulb. Both suggested that electric current should be laid on to houses and buildings like water or gas, but Edison was the first actually to do this work. That happened between 1878 and 1880.

Edison saw that the voltage or pressure must not be too high, and also that it must be possible for each light to be turned off or on without affecting other lights. This meant that the voltage must be somewhere about one hundred and that each lamp must have its terminals connected to two supply-wires. Edison saw also that he must have several dynamos in action, so that all the eggs would not be in one basket.

In those days, of course, there was no maker of electric-light appliances, and Edison had first to invent each one separately, and then to make it. He selected as his standard pressure a supply of one hundred and ten volts, and designed constant-pressure, shunt-wound dynamos, with drum armatures. In these the field electro-magnet consisted of two massive iron pole pieces at the end of long iron bars, or legs, which were wound with magnetizing coils and connected at the top by an iron yoke. These dynamos were separately driven, but sent their currents into a common pair of electric mains called 'bus bars.'

In 1879 Edison lighted the streets and some buildings in the suburb of Menlo Park, including his laboratory, office, and three houses. On New Year's Eve, 1879, three thousand people came to see the new lighting. Later Edison equipped a steamship, the *Columbia*, with about one hundred lamps, and this installation worked well for several months. The lamps withstood a voyage round the Horn to San Francisco, and were inspected with much interest at Rio de Janeiro, Valparaiso, and other ports. But as Edison has since said: "We had a successful lamp, but it was not economic. It was fragile and costly, and it was evident that our carbons were not made of the right substance."

At the same time in England Swan was using parchmentized cotton. He actually produced a bulb electric lamp before Edison, but both had similar trouble in obtaining a filament that was sufficiently strong to last. Edison tried some six hundred different varieties of vegetable carbons, including forty sorts of bamboo, while among other things Swan made trial of viscose, the raw material of artificial silk. When his assistant, Topham, at last succeeded in spinning this silk a very fair filament was secured. Yet none of these early carbon lamps was lasting, and years passed before the inventors made a lamp which could be relied on to have a life of more than about one hundred hours. Also the lamps were so fragile that the difficulty of packing them for transportation was very great.

It is interesting to remember that a committee was appointed by Parliament to examine into the subject of electric light. This committee had before it as witnesses nearly all the prominent scientists of the day, and all, with the solitary exception of Tyndall, testified that in their opinion a practicable system of electric light for private houses was impossible.

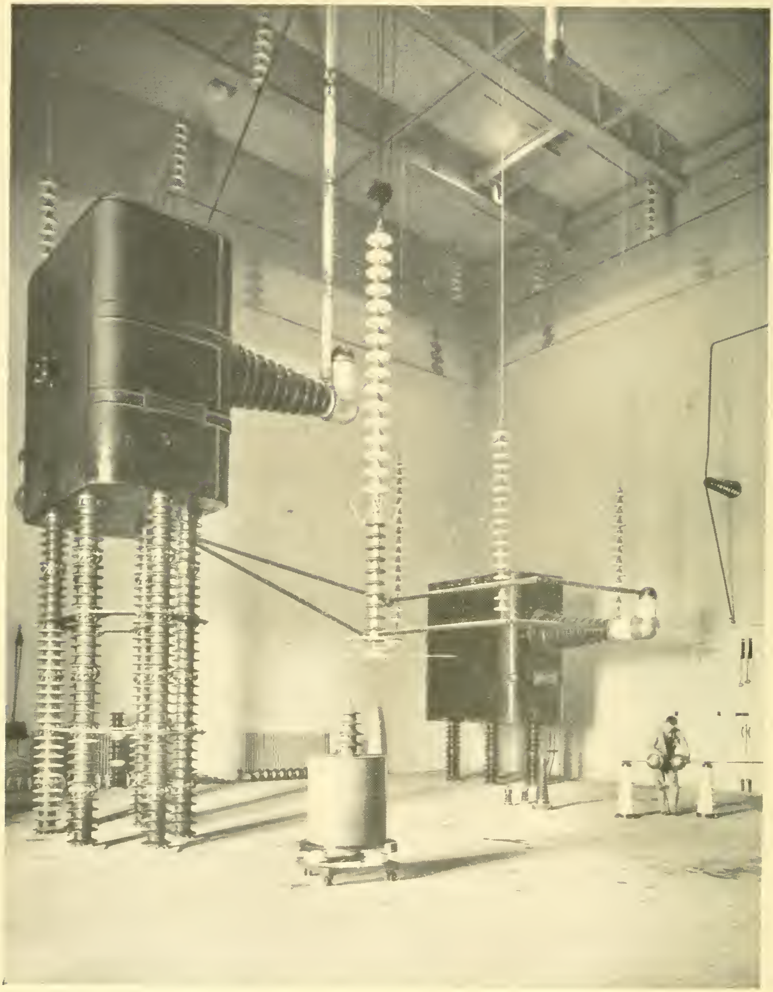
Yet the Edison Electric Lighting Company of London was formed in 1881; then the Admiralty took the matter up and allowed the company to tender for the lighting of certain Indian troopships. By 1882 there were no fewer than one hundred and twenty electric lighting stations in the United States, paying dividends of from six to fourteen per cent.

Then the British Parliament proceeded to pass an Act for facilitating electric lighting, an Act which very nearly killed the invention so far as Britain was concerned. It provided that electric supply should be undertaken only under orders from the Board of Trade, and that any town where such works were started should be able to buy them at the end of twenty-one years at the value of the plant and works, without taking into account the goodwill. Of course people were not going to invest their money in order to make presents to municipalities, so for six years Great Britain had scarcely any electric lighting at all. Then a new Act was passed increasing the purchase period to forty-two years, and since this gave investors a fair chance of some profit on their money matters began to improve.

In the early days of electric lighting direct current was used, and the wastage of course was great. It was that remarkable genius Ferranti who first began to use the alternating current transformer system. Most of our readers know enough about electricity to be aware that it is out of the question to use high voltages for small lamps. You would simply burn them out, fusing the filament. Yet the high-pressure alternating current is far more economical than the direct, and can be sent over much greater lengths of cable. Ferranti was the first to employ transformers to ' step down ' the high voltages to lower, thus making them suitable for domestic use. He did this first in the Bond Street district in London in the year 1885, showing that it was possible and practical.

Ferranti was a particularly far-seeing inventor. He was the first to realize that electric supply stations for a great city like London must be placed outside the area to be supplied, in some position where coal and water can be obtained easily. To-day, practically all the great supply stations are on rivers from which the water for the boilers and for condensing purposes can be pumped up easily, and most of them have their own railway sidings, where coal can be dumped at the foot of an elevator by which it is carried upward, to be dropped into the furnaces as required.

It was Ferranti who succeeded in starting the large



THE 1,000,000-VOLT TESTING TRANSFORMER IN THE RESEARCH LABORATORY AT STOURPORT station at Deptford on the Thames, to supply current at ten thousand volts pressure to transformers in the London area. For this station he designed great fifteen-hundred horse-power alternators worked by Corliss engines, and since ordinary copper wire was not suitable for carrying so heavy a current he invented a form of main consisting of two copper tubes, one inside the other, and insulated one from the other by Manila paper soaked in certain resins and oils. The writer of this chapter was shown a small piece of Ferranti's original main, which is preserved in the office at the Bedford Power Station.

These first mains were seven miles long, and four cables were laid. They carried their load well enough, but very strange things began to happen. A large current was found to flow into the Deptford main when no current was taken out at the London end, and it was discovered that these long mains actually became condensers—you might say Leyden jars, each with a very considerable electric capacity. But the worst trouble was this. When these long concentric mains were switched on suddenly or disconnected there was often a failure of insulation between the outer copper tube and the protecting steel tube. This was due to the ' mass ' of the electric current. The problem was solved by Partridge, the Electric Supply Company's engineer, who devised a means for switching on the current gradually instead of suddenly.

Another valuable invention of those early days was the 'cut-out,' the function of which is to interrupt the current in a main or branch should it exceed a safe strength, as may happen in the case of two wires short-circuiting. A cut-out is a safety fuse inserted in the circuit; usually it is made of a short piece of lead wire, which will melt if the current becomes too strong.

In spite of many experiments, it was a long time before anything better than the carbon filament for lamps was discovered. True, the lamps were so much improved that their life was increased from one hundred to as much as one thousand hours, but still they were not satisfactory, for a carbon filament gradually breaks up, and after a time these lamps lost their illuminating power.

The first improvement was the so-called 'squirted' filament. We have mentioned how Topham made a filament by the use of liquid viscose. It was found that by dissolving cotton-wool in zinc chloride the material called cellulose could be made. This was forced through a die and 'squirted' into a very fine thread; after washing and drying the thread was carbonized in a closed box in a furnace. Loops of this material were treated by depositing fresh carbon upon them, and yielded a more uniform filament than could be made of bamboo or woven thread. The melting-point of these carbon threads was about seventeen hundred degrees Fahrenheit.

Many inventors were busy making substitutes for carbon, but the difficulty was to find a material which could be raised to a higher temperature than seventeen hundred degrees without melting. Platinum was tried, but found to be useless. It was known that certain of the rarer metals, such as tungsten, tantalum, and molybdenum, had melting-points higher than platinum, but in those days there was no supply of these metals, which were merely curiosities of the laboratory.

In 1897 Nernst brought out his new lamp; this contained a rod of oxide of magnesium mixed with oxides of other rare metals, heated by a white-hot platinum spiral. It was a good lamp, it gave a fine light, and lasted better than the carbon, but the worst of it was that it took about fifteen seconds, after the turning on of the current, to give its full light. However, it served well until replaced by the metallic filament lamp.

The first metalled lamp was the tantalum made by Siemens Brothers, but this, in its turn, gave way to the tungsten lamp, which is still in use. Tungsten is a metal so hard that it can only be fused in an electric furnace, yet it can be drawn into exceedingly fine wire which gives a beautiful and economical light.

The gas-filled tungsten lamp introduced just after the War is still more economical. The gas used in these bulbs is argon or nitrogen, or some other inert gas which allows the tungsten to be heated very highly without melting. These wire-drawn lamps have a much longer life than the older carbon lamps, and the saving is indicated by the fact that a big London shop, whose bill for electricity used to be four thousand two hundred pounds a year, now lights for about twelve hundred pounds.

Very large lamps can be made for street lighting on the wire-drawn plan. Some of these are of as much as two thousand candle-power. By the way, we all talk of candle-power, but very few of us know exactly what it means. This standard was laid down as long ago as 1860, when it was necessary to fix a standard for gas-lighting. The measure is a candle made of spermaceti and beeswax, weighing six to the pound, and burning at the rate of one hundred and twenty grains of spermaceti to the hour.

Science has given us lamps without any filament at all. One is the mercury-vapour arc lamp used for night photography. A small amount of mercury is placed in each end of a vacuum tube. The arc is started by tilting the tube so that a stream of mercury unites the two pools for a moment, then separates. Then an electric discharge continues through the mercury vapour. The light is a brilliant green, and makes people's complexions look so ghastly that it is not suitable for domestic use. Another wireless lamp contains neon gas, which gives a lovely rosy glow.

Proud though we are of our electric light, our descendants will wonder how we could have been satisfied with such a wasteful form of lighting, for even by the best tungsten lamp the amount of light given out is less than eight per cent. of the power used to heat the filament. The firefly and the glow-worm can give us points and a beating, for they—and they alone—have the secret of producing *cold* light. It is calculated that the luminous efficiency of the firefly is between ninety-five and ninety-seven per cent. Their light is true luminescence, whereas our electric light is produced by heat. The creation of cold light is one of the great tasks which is awaiting the scientists of the present century.

We have written at length about electric lighting because we are most familiar with the electric current in this form, yet it is only one of very many forms, of course, in which electric power is employed. A great many industries depend so entirely on electric power that they could not exist without such a supply. Calcium carbide, from which acetylene gas is obtained, is made by mixing coke and lime and shovelling them into the electric furnace of which it is essentially a product. Carborundum, next to the diamond the hardest substance in the world, is made by the cheap electric power generated at Niagara Falls. A few years ago aluminium, now used for all sorts of things, from cooking-pots to flying-machines, was a mere curiosity of the laboratory. This metal too we owe to the electric furnace. The ore of aluminium is cheap enough, for it is only a clay, but the amount of current needed to make one ton of aluminium is no less than thirty thousand units, or forty times as much as is required for making a ton of steel. At Foyers, on Loch Ness, the British Aluminium Company use a waterfall which gives thirty thousand horse-power.

Through increasing demand the supply of natural saltpetre no longer meets the world's requirements. Saltpetre provides nitric acid, which is essential in the manufacture of explosives, while nitrogen is the most valuable of all plant-fertilizers. To combat the famine in saltpetre, nitrogen is now drawn from the air by a process which depends entirely on electric power. In Norway four hundred thousand horse-power is used in producing nitric acid by this process, and the output is one hundred and eighty thousand tons yearly.

Electric furnaces are used for the making of special steels. Before the Great War the amount of power used for this purpose in Great Britain was only about three thousand horse-power a year, but by 1918 it had risen to no less than one hundred and thirty-five thousand horse-power, and electric steel was being produced at the rate of two hundred thousand tons a year. From seven hundred to eight hundred units of electricity are used in making a ton of electric steel.

Here it may be convenient to explain what is meant by a unit of electricity. One B.T.U. (Board of Trade unit of energy) is sufficient to heat about two gallons of water from the temperature of the melting-point of ice to boiling-point.

Electric power is largely used in making brass, but power must be cheap for this purpose, because every ton melted requires two thousand units. Another important industry is the electrolytic recovery of zinc, a process which absorbs no less than five thousand units per ton. A large factory has recently been erected for this purpose in Tasmania, where water-power is easily obtainable. Chromium, the metal which gives to rustless steel its special qualities, is prepared in electric furnaces, and so too is rustless steel itself.

Another very important electrical industry is the manufacture of graphite. Graphite, which is a form of carbon, is much used as a lubricant and for making crucibles. It is best known, however, as the black-lead in pencils. Acheson, the American scientist, noticed that the crater end of a carbon that had been used for arc lighting turned to graphite. Then he discovered that a small amount of silica greatly assisted the change, and worked out a new process. In this powdered anthracite coal is mixed with a small proportion of sand, and then when electrically heated produces graphite. At Niagara some six thousand tons of graphite are made yearly by the Acheson process.

Cheap electricity will cause a revolution in British households, which will not only light but also cook by electric power. There will be no need for ice, because electrical refrigerators will keep food cold and sweet, nor for brooms, because electric vacuum-cleaners will extract the dust far more quickly and cheaply. Electric fires will keep the rooms warm in winter, and electric fans will cool them in summer. A sewing-machine can be run all day for a pennyworth of current, and curling-irons can be conveniently heated for a minute sum. The old clumsy hot-water bottle will be superseded by the electric bed-warmer, which is just a harmless wire in a woollen bag. Knives can be cleaned by electricity, and toast can be made fresh and crisp on the breakfast-table. Many women have realized already the advantages of using the electrically heated flat-iron.

Dust and dirt will disappear in the electric house, and disease germs will vanish with the dirt. Perhaps the greatest benefit of cheap electricity will be that we shall all be able to use artificial sun-baths in our own houses. Rheumatism, colds, and skin diseases will be defeated, and we shall enjoy better health than ever before.

Some people are still nervous about introducing electrical power into their houses. They are afraid of fire or of getting shocks. There is no excuse for any such fears nowadays, for insulation is practically perfect, and the fuses guard against any danger from an increase in current. For cooking-stoves a low voltage is usually employed, so that there is little risk even if anything does go wrong, which is very unlikely.

And what of the power stations themselves? When asked this question, the engineer in charge at Bedford said: " They are so nearly fool-proof that even a drunken man turned loose in one could hardly hurt himself." It was not always so, for in the old-fashioned switch there was metal carrying two thousand volts on either side of the switch handle. For a healthy person two thousand volts is a dangerous yet by no means a fatal shock, though people with weak hearts have been killed by a shock of no more than one hundred volts.

Having asked whether the overhead cables were affected by wind or weather, we learned that they are made to withstand gales of fifty miles an hour and three-eighths of an inch of ice forming on the wires themselves. They are fitted with earth wires which form an almost perfect protection against lightning, and with bird guards which prevent large birds such as jackdaws from forming connexions between charged wires, and incidentally electrocuting themselves.

Almost the only danger is that a gale may break off a tree branch and blow it against two cables, thereby causing a short circuit. Even wet straws blown against the poles in a mass may cause a short circuit, but this rarely happens.

It is through the kindness of Sir John Snell that we have been able to write this chapter on the modern developments of electric power. Sir John Snell is a Cornishman. He was educated for the Navy, but fortunately or unfortunately he failed to pass the very strict eyesight tests. He turned his attention to engineering, and became a student at King's College, London, of which he is now a Fellow. When only fifteen he went to work for the firm of Messrs Woodhouse and Rawson, and afterward went to Stockholm. He was only twenty-three when he became assistant to Major-General Webber, R.E., and three years later he held the important post of Borough Electrical Engineer at Sunderland. In 1910 he was a partner in the firm of Messrs Preece, Cardew, Snell, and Rider, and was chosen as principal technical witness in the taking over of the National Telephone Company by the Post Office, a very big and complicated transaction. Millions of pounds of property had to be valued before it could change hands. So began his connexion with the Government.

In the Great War Sir John was one of the five original trustees appointed by the Army Council to form the Metropolitan Munitions Board, and he was a member of the very important Nitrogen Products Committee. Nitrates, of course, were of the very greatest importance for the making of explosives. Sir John is chairman of the Electroculture Board. This branch of electrical work is described in the chapter dealing with the career of Sir Daniel Hall.

In 1920 Sir John Snell became chairman of the Electricity Commission, and in this work he is still actively engaged.

CHAPTER XXIII

WHERE LIFE ON THE EARTH BEGAN

Sir Arthur Thomson and Once upon a Time

"MY chief convictions," says Professor Sir Arthur Thomson in a letter to the writer, "are (1) biology for the service of man; (2) the necessity for religion."

What is biology?

In *Chambers's Encyclopædia* it is defined as "the science that seeks to classify and generalize the vast and varied multitude of phenomena presented by and peculiar to the living world."

In one sense biology is the oldest of the sciences, for even the savage observes the different forms of life around him; he gives names to the various animals, birds, and plants, and learns the uses of each, and to some extent their habits.

The biologist is better known as the naturalist, and naturalists are divided broadly into botanists and zoologists—those who deal with the plant and animal kingdoms respectively. The modern biologist, such as Sir Arthur Thomson, is concerned with all branches of life, and seeks for knowledge of the laws that govern their organization and activity.

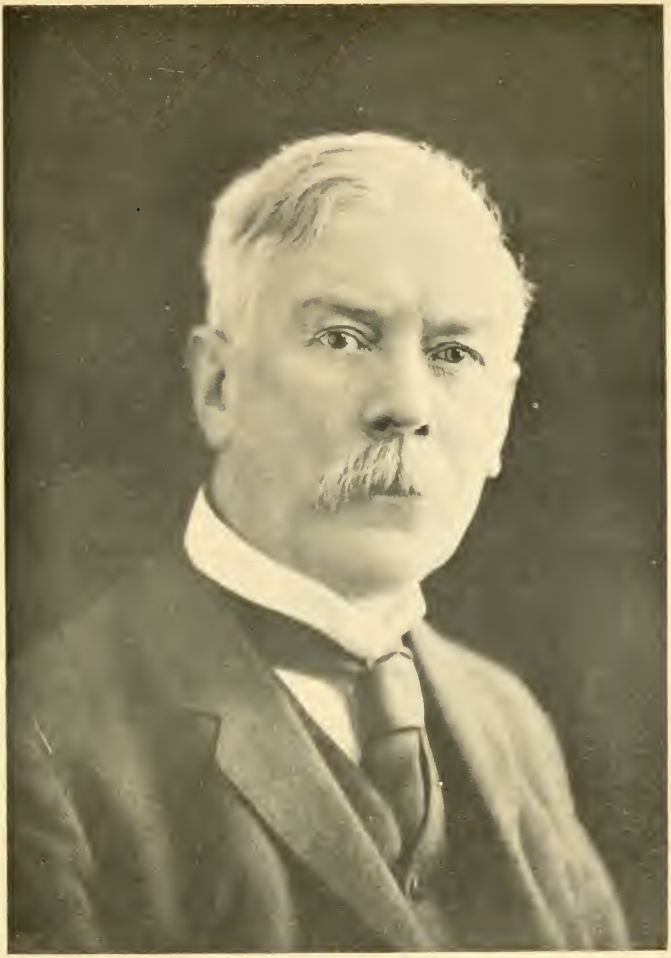
For a long time naturalists occupied themselves chiefly in describing the outward characteristics of animals and plants, and in classifying them in accordance with appearance or habits. The French botanist de Jussieu, who was made superintendent of the royal gardens of the Petit Trianon in 1758, was the first to make a new grouping of plants on the basis of their 'comparative anatomy.' So by degrees the science of biology developed until biologists penetrated beneath the surface and began to study the organs of animals and the tissues of plants. Schleiden the botanist discovered in 1838 that all plant substances were built up of cells. To-day natural history goes so deep that it has become closely allied to chemistry and physics.

One of the merits of biology is that it teaches man so much about his own beginnings. Man has been on the earth for a very long time, yet, comparatively speaking, he is a newcomer. Says Sir Arthur:

> If we could arrange a great cinema film of the evolution of living creatures, giving proportionate lengths to the successive organic dynasties, arranging the whole so that it could be unrolled at uniform rate throughout a day, beginning at nine in the morning, then man would appear a few minutes before midnight. . . . Yet man only, among all living creatures, is aware of the long drama, and even he has but a dim understanding of the plot.

It is through the work of men such as Sir Arthur Thomson that we begin to have some idea of the beginnings of life on this planet. At first the earth was a ball of flaming vapour, which gradually cooled and contracted until it had a solid crust. A most unpleasant crust, for it was smoking and cindery, and the atmosphere, such as it was, would have poisoned any living being. There was certainly very little oxygen, for most of the oxygen in the air has been made out of carbonic acid gas by green plants working in sunlight. At first there was no sunlight at all. The light was cut off by enormous masses of cloud, such as still surround the planet Venus.

By degrees the earth's crust cooled, rain began to fall, and pools of water appeared. In the course of ages these pools grew to seas, which dissolved the salts out of the earth and themselves became salt. It is possible that at



SIR J. ARTHUR THOMSON

Photo by Elliott and Fry

one time the whole surface of the earth was covered by one great shallow sea. In these seas life first appeared. How it came we do not know, and this is not the place to discuss this greatest of all problems. The first living creatures were certainly very small. They were half plants, half animals, which swam about in the warm, brackish water, but it was they who began the process of splitting up the heavy carbonic acid gas, fixing the carbon and liberating the oxygen, and so improving the air and by degrees making it more fit to breathe.

As the continents rose some of these living things had a chance of settling down, and so began the race of seaweeds. In the course of ages the seaweeds worked up the mouths of rivers into fresh water, changing by degrees and very slowly into mosses and ferns. We know from examination of the deep coal-measures that the early forests consisted of giant ferns such as still exist in New Zealand.

Meantime there was another change taking place in the seas. Some of the half-plants turned into animals. The plants had been content to feed on what they could get from air, water, and soil, but these new creatures would no longer live in that way. They moved about and fed upon the plants themselves, and so gained energy and increased in size.

"These," says Sir Arthur, "tried experiments along many lines and gave rise to sponges, zoophytes, corals, and jelly-fish." Most likely they lived in the shallow waters near the shores, creeping or swimming among the beds of seaweed. We may be quite certain that animal life began in the water and not on the land.

One proof of this is open to every one, for if you cut your finger and suck it you find that the blood has a strong salty taste. The salts in your blood are almost exactly the same as those in sea-water.

Sir Arthur Thomson believes that the first living creatures to be successful were open-sea creatures, half plants, half animals, able to swim by means of a living lash. In the open sea there still survive many creatures of this kind—flagellates, as they are called—which swim in this way, and seem still to hesitate between the animal and vegetable kingdoms.

As these creatures of the weed-belt increased in size and numbers, some worked closer and closer to the shore. These had to become hardy in order to withstand the breaking surf. The tides, greater in those early days than they are now, must have left many stranded high and dry, and at length some became able to endure this ordeal. They were shellfish similar to the limpets and whelks which we all know so well. But not all the new creatures were able to withstand the tumble of the waves and the sweep of the tide on the beach, and of these some ventured farther and farther out from the land, becoming open-sea creatures.

Others, again, worked their way down the sloping sea-floor toward the 'mud line.' They were principally soft-mouthed creatures such as sea-worms and sea-cucumbers, which live upon soft particles—'crumbs,' as Sir Arthur calls them—that have sunk down from above. Slowly these followed their food to greater and greater depths, changing their form and habits so as to become suited to life in the sunless chill of the deep sea. One of the most interesting discoveries of the past century is that life not merely exists, but is plentiful down to the very bottom of the abysmal deeps such as are found off the coasts of Japan and close to the Philippine Islands.

Right up to the middle of the nineteenth century naturalists spoke of the deep sea as being devoid of life. It was not until 1860, when a deep-sea cable was lifted in the Mediterranean from a depth of six thousand feet and fifteen living animals were found attached to it, that the truth began to be suspected, but man had to wait until the famous voyage of the *Challenger* (1872–6) for the discovery of the new world of the deep sea.

During this cruise the *Challenger*, with Darwin aboard, covered nearly seventy thousand miles, and raised treasures of life from the depths of almost every ocean. There are no plants in the great depths, there are no bacteria, but there are sea animals in wonderful profusion and variety, from huge cuttle-fish down to dainty, fragile organisms such as the so-called Venus flower-basket. Living in utter darkness, many of these creatures have developed lights of their own, and glide along lit up like little ships. Of life in the deep sea Sir Arthur says:

> It has been of value to mankind practically in connexion with laying cables; intellectually, for it has been an exercise ground for the scientific investigator; emotionally, for there is perhaps no more striking gift to the imagination than the picture which explorers have given of the eerie, cold, dark, calm, silent, plantless, monotonous, but thickly peopled world of the deep sea.

The flounder, originally a sea fish, is often found some distance up fresh-water rivers. For some reason of its own it is learning to live in fresh water, yet it has to return to salt water to spawn. There are other fish, such as salmon, sea-trout, and shad, which can live either in salt water or fresh, and here we have a clue to the first peopling of the fresh waters from the sea. Either sea fish behaved as the flounder is now behaving, or perhaps an arm of the sea was cut off by a rise of the land and so became an inland lake. This, by the inflow of streams, would become first brackish and at last fresh, but the process would be slow enough to enable its inhabitants to become accustomed to the new conditions. Lake Baikal, in Asia, is an immense distance from the sea, and is now fresh water. Yet seals inhabit it, and seals are marine animals. Here is proof that Baikal was once part of the sea, proof, too, that sea mammals can change their way of life.

Another instance which Sir Arthur gives of a sea animal invading dry land is that of the robber crab of Christmas Island. Christmas Island is in the Indian Ocean, two hundred miles south of Java, and is famous for its great beds of phosphates, which are very valuable as a fertilizer. It was the *Challenger* Expedition which made this discovery, and the whole cost of that expedition was repaid from royalties deriving from the sale of these phosphates.

The robber crab, a fairly big creature, is plentiful on Christmas Island; it has gained its name because, like the American trade rat, it is fond of getting into houses or workshops and stealing things. One has been seen making off with an empty meat tin and using this as a protection for its tail. It also climbs coconut trees and breaks off the nuts. Then it climbs down, tears off the husk of the nut, breaks a hole in the shell with its immense claw, and spoons out the sweet milk with one of its legs.

A queer beast indeed, and, as Sir Arthur says, specially interesting in the story of evolution, because beyond doubt it was once a marine animal. And it betrays its origin by the fact that once a year it goes back to the seashore to lay its eggs. The eggs are dropped in the sea, and the young crabs, when hatched, live and swim in the salt water for some considerable time. Then they come back and creep on the shore, and at last become strong enough to go inland and live there.

Sea creatures breathe by means of gills; these are feathery growths, and inside them the blood runs through numerous small veins and takes oxygen from the water which bathes the gills. Land animals breathe by means of lungs which are inside the body. How then can a gilled creature live on land? If you examine a robber crab you find that it still has traces of gills, but on the walls of the gill chamber the crab has produced delicate projections which contain blood and are able to absorb dry air.

There are other kinds of land crab found in the West Indies and elsewhere, and these, like the robber crab, have to go back to the sea to produce their young. They are examples of a change which is comparatively recent. Sir Arthur Thomson gives an example of another change as strongly established, yet much older.

If you break off a piece of bark from a decaying log you will almost certainly find beneath it one or more of those odd little many-legged, armoured creatures called wood lice. Count the legs and you find that the creature has nineteen pairs. This means a great deal, for almost all lobsters, shrimps, and prawns also have nineteen pairs. This is not a mere coincidence, but proof that the wood louse, a land creature, sprang originally from the marine sea-slaters or isopods, which are often found between high- and low-tide marks "beginning the exploration which the wood lice have finished."

Likewise earthworms, which drown in a puddle, undoubtedly sprang from water-worms. A proof of this is that there are several varieties of earthworm which still have gill-like outgrowths near the head end.

The invasion of the land by the worms was of great importance to man, for it is worms more than anything else that have made fertile soil fit for plants. This invasion was followed by what Sir Arthur calls the "centipede-millipede-insect-spider invasion," which was also of great importance, because it linked the flowers and flower-visiting insects. Third was the great amphibian invasion, starting probably with certain bold fresh-water fishes. In India to-day there is a kind of small fish which crawls out of the water and clings to the bank high and dry. Millions of years ago the same sort of thing happened and fish became amphibious (able to live on land or in water).

So came into being the reptiles which for ages formed the only life on land, and these in turn evolved into the mammals (warm-blooded animals) and the birds.

The best and biggest change, says Sir Arthur, was that which took life into the air, and he tells us that there were no fewer than four different invasions of the air. First, an invasion by insects, which have now become the most plentiful of all living creatures; secondly, an invasion by flying reptiles, such as the pterodactyl (this was not a successful invasion and lasted only for a time); third came the bird invasion; and lastly that of bats, warm-blooded animals that took to flight.

It is partly by observation of existing animals that we are able to learn the long story of the evolution of species, but our best books are the rocks and the fossils which we find in them. We speak of the solid earth, yet continents and mountain ranges are continually rising and sinking. Rain and rivers are always carrying down sand and gravel from the high grounds, and these, deposited elsewhere, harden into rocks. So the earth gets skin after skin, and the rock record is like a library with the oldest books on the lowest shelves. Some of the shelves are broken, some volumes missing, yet practically the whole story is there to read, and never a year passes without fresh information coming to light. The story is not finished, but still goes on, and if astronomers are right it may continue yet for many millions of years. It is only recently that scientists have proved their theory of evolution—the slow, natural process of racial transformation—and the causes are still mysterious.

" Life," as Sir Arthur writes, " continues to flow up hill."

There is not merely change, but constant improvement. Nature is always making experiments. Some, like that of the flying reptiles, fail and are abandoned. We will conclude this short account of the origin of life with a paragraph quoted from Sir Arthur's *New Natural History*, published by Messrs Newnes, Ltd.

> When we try to get a picture of the sublime process of organic evolution, which has no doubt continued for several hundred million years, we receive certain great impressions. One is the multitudinous production of individualities; there are over a quarter of a million different kinds of living animals each itself and no other. A second impression concerns the persistence with which every possible haunt of life has been and is being peopled—from sea to land, from earth to air. A third is centred on the establishment of fitness after fitness—often with a marvellous *nuance* of adaptation. And then there is the largest fact—that in the course of ages, the mental aspect became increasingly manifest and masterful.

John Arthur Thomson comes of a family of naturalists. His father, a clergyman, was a keen botanist; his grandfather, also a clergyman, was a good zoologist, and the future biologist was brought up in the country. He studied at Edinburgh University, and then under the famous Ernst Haeckel at Jena. He worked in Berlin, at the Marine Biological Station in Naples, and was later lecturer on zoology and biology at the School of Medicine in Edinburgh. For thirty years he was Regius Professor of Natural History at Aberdeen University, where he formed one of the best small natural history museums in the kingdom. Hardly any living naturalist has written more widely upon nature, or more interestingly. In 1930 recognition was given to his work when his name appeared in the Birthday Honours as the recipient of a knighthood.

CHAPTER XXIV

WHEN THE WORLD WAS YOUNG

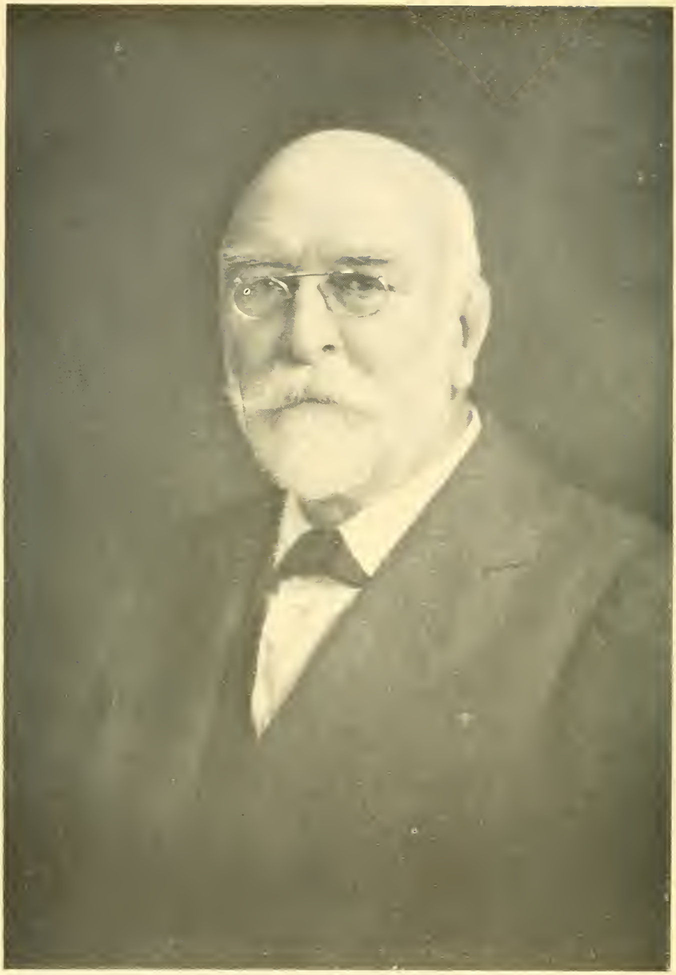
Sir Arthur Smith Woodward Investigates the Remote Past

SOME thirty years ago there was serious trouble between the Argentine Republic and Chile. It was the usual South American quarrel over the question of boundaries, and the two countries were very near to war when some one had the good sense to suggest that it might be better to ask King Edward to act as arbiter. Both countries agreed, and a Commission was appointed to examine the boundaries before going to England to put the case before King Edward.

One of the Argentine Commissioners was a Señor Moreno, a wealthy man who was also a very keen scientist. He had already founded a museum at La Plata, which has since been handed over to the State; it is said to be the best of its kind in South America.

Now the boundary-line of the two countries runs down to the very end of South America, through wild and little-known Patagonia, and while Moreno was exploring he came upon a *rancho* near the south coast at a place which bore the rather sinister name of Ultima Esperanza ("Last Hope"). There Moreno put up for a day or two, and one of the first things he noticed was a great slab of thick skin hung up in a tree near the house.

Most people would doubtless have taken it for an ox-hide, for in Patagonia the nearest tree is used as a larder where the meat is hung, but, luckily for Science, Moreno saw at once that this was not an ox-hide, but something very different. He examined it and saw that it was very



SIR ARTHUR SMITH WOODWARD

Photo by Lafayette

thick, and that while the outer part had coarse hair on it the inner side was full of little bones.

Going back into the house, Moreno made inquiries, and was told that this piece of skin had been found in a cave near the shore. Moreno again examined the skin, and came to the conclusion that it was part of the hide of the mylodon, a creature commonly called the giant sloth. Bones of this creature had already been found, but it was believed to be extinct. Yet this piece of hide looked amazingly fresh. The hair was still on it, and there was even a blood clot. It was not in any respect fossilized.

The next thing to do was to examine the cave; there Moreno found other fragments of skin and bones of the same animal. The cave he found to be singularly dry, while everything was covered with a thick dust containing a quantity of saltpetre. This explained the wonderful state of preservation of the hide. The owner of the *rancho* parted with the relic, and Moreno took it with him to London, where he called in his friend, the distinguished geologist Doctor (now Sir) Arthur Smith Woodward, who made a microscopic section of a morsel of the hide and confirmed Moreno's opinion that it was indeed the hide of the giant sloth.

We think of a sloth as a rather small, stupid, hairy animal that spends its uneventful life hanging upside down in the trees and living on leaves, but this giant sloth was not a tree-climber. It lived on the ground, walking upright like a kangaroo, and grazing on the branches of trees. It may have stood twelve to fourteen feet in height, and weighed a ton or more.

The discovery caused a great sensation, and a London daily sent out a special correspondent, Hesketh Prichard, to explore the surrounding country and discover, if possible, whether the giant sloth still survived. Meantime Germans living at Punta Arenas, the most southerly town in America, sent a small expedition to explore the cave, and there got more skin and bones. They also collected two bird's nests partly made of hair plucked from the hides of these extinct giants. But the most interesting discovery made was that these animals must originally have been *kept in the cave by human beings*. The date at which this happened cannot be definitely fixed, but it may well have been within the past two thousand years.

The relics collected by these Germans came into the hands of a rich Jew who lived in Berlin. As soon as Dr Smith Woodward heard of this he went off that very same night to Berlin and interviewed the owner, who told him that the Kaiser was going to buy the remains. Dr Smith Woodward wanted them badly for the British Museum, but he felt that it was impossible to bid against the Kaiser. He then went to see the scientist who usually advised the Kaiser on these matters, and, learning from him that he was not recommending the purchase, Woodward hurried back to the Jew and made him an offer. It was accepted, and, thanks entirely to Dr Smith Woodward, these most interesting remains are now to be seen at South Kensington.

In talking to the writer Sir Arthur mentioned the interesting fact that bones of horses were found in the cave where the remains of the mylodon were discovered. The interest of this discovery will be appreciated when it is explained that when white men first reached America there was not a horse on the continent, North or South. Yet in both North and South America fossilized horse bones have been dug up in large quantities.

Sir Arthur Smith Woodward is best known for his researches connected with the antiquity of man, and more particularly in connexion with the Piltdown skull, the oldest human skull ever found in Europe. This skull was actually discovered by Charles Dawson, a solicitor of Lewes, who had already discovered the natural gas of

Heathfield, in Sussex. Dawson was a remarkable man; when only twelve years old he had already started a collection and was spending all his pocket-money on the purchase of fossils from the quarrymen at Hastings. The hours which most boys give to games he devoted to tracing out fossil footprints of the giant reptiles which once inhabited England, and to digging out their bones and piecing them together.

Great fish, tiny shells, and delicate fossil ferns—all were collected by this enthusiastic youngster. By 1884 his collection had already grown too large for any private house, and he offered it to the British Museum. His friends had looked on the whole thing as a mere boyish pastime, and they were greatly surprised to see experts from the British Museum spending whole days in carefully packing the specimens for their safe journey to London. The national museum was only too glad to have the Dawson collection in exchange for its original cost.

Thenceforth for many years Dawson continued to spend all his leisure in collecting fossils, and he came to know the South Downs and their treasures as perhaps no other Englishman has ever known them. In 1897 he announced to the Geological Society his discovery of natural gas in Sussex. The flow continues, and natural gas still lights the railway-station and hotel at Heathfield. Dawson discovered a Roman pile at Pevensey, identifying the place with the Anderida of the Romans, and he has written on Bronze Age bracelets, the Lavant caves, on Sussex iron-work, and many similar subjects.

Finally it was this same enthusiastic amateur who discovered the remains of Britain's oldest known inhabitant. The find was made in the gravel of a river which has long since ceased to flow. In fact it is so long since it flowed that the whole face of the country has changed and now there is no river near. In the bed of this long-lost stream was a deposit of gravel which had evidently been formed by a strong eddy. Every flood that came down, washing with it odds and ends from upstream, left remains in the bottom of this deep whirling pool. There were bones of long-extinct animals, flint instruments, and finally, greatest treasure of all, there was dug up in the late autumn of 1912 part of a human skull.

After examining this Sir Arthur pronounced it to be that of a different species of man older than any yet known, to which he gave the generic name of *Eoanthropus*. His interpretation was at first the subject of much criticism by certain anatomists, but later discoveries of a tooth and other small portions of the skull proved that he was right.

The skull was that of a woman, and it is certain that at least fifty thousand years have passed since she walked the soil of England. It may be a very much longer period, and some geologists have estimated it at two hundred thousand years. The woman was semi-simian —that is, she combined in herself the traits of a human being and the characteristics of the ape. She was nearer, indeed, to what is generally called the "missing link" than any other creature of which remains have been found.

What was actually found was only a portion of the left-hand side of the skull and a piece of the lower jaw, but with these as a guide there has been built up a faithful and reliable model of the whole skull, and this may be seen in the South Kensington Museum. No modern human being possesses teeth of the size or shape of those seen in this reconstructed model; these and the heavy under-jaw emphasize the ape-like characteristics of the Piltdown woman. Another point is that the brain development is only about two-thirds of that of the modern woman, being sixty-four and three-quarter cubic inches as compared with ninety cubic inches.

It is certain that the race to which this woman belonged could not talk—at least, as we understand talking—although they could doubtless make sounds which were understood by one another. The jaw lacks the inside ridge to which muscles controlling the tongue of a 'talking man' are attached. Yet the back teeth were human teeth, and the top of the skull has human characteristics. The ancient race to which the Piltdown woman belonged were not apes, but men. They walked more or less erect, and probably used weapons of some kind, rough flints and clubs with which they killed animals for food. Whether they were able to make fire or not we do not know.

Since the discovery of the Piltdown skull another skull of immense age has been found in South Africa. Its discoverers consider that this may belong to the Pliocene epoch—that is, that it may be half a million years old—but the best authorities do not consider that these remains are human. They belong definitely to the ape family. This particular ape, however, seems to have been intermediate between living apes and mankind.

No one can tell the age of the human race, but flint implements have been found which date from long before the last Ice Age. In a paper read some years ago before the British Association Dr Allan Sturge spoke of bronze implements found in Egypt by Professor Flinders Petrie which were some fifteen thousand years old. " But," he said, " I shall take you, by the aid of these flints before me, immeasurably further back."

He showed his audience a wedge-shaped piece of flint, the marks on which told him, he said, that the stone had been used daily by a man of the Palæolithic (Old Stone) Age in a village in England. This man had thrown it away, and for thousands of years it had lain idle, until a Neolithic (New Stone) man had come along and chipped it afresh for his own purposes. Then he too had thrown it away, and it had lain deeply hidden beneath the rubbish of thousands of years until it had been found again, and held up by a twentieth-century lecturer before his audience.

Another flint implement which Dr Sturge showed had upon it scratches made by ice. Now an Ice Age comes round only once in about twenty thousand years, so that this particular flint tool had certainly been made before the last Ice Age.

These early and ape-like men were succeeded in South-western Europe by another and much more highly developed race called the Aurignacian. These people have left us proof of their artistic ability in pictures cut or painted on the walls of the caves which they inhabited. Most of these pictures are found in caves in the department of Dordogne, in France. Sir Arthur Smith Woodward is one of those who have examined them.

The work is astonishingly good. There is nothing of the stiffness of the Egyptian draughtsmanship, yet these semi-savage artists were working thousands of years before Egypt had reached even the dawn of civilization. Almost all the wild animals of that remote period are pictured in these caves, including a number that are now extinct. There are, for instance, drawings of the great hairy mammoth, of the huge cave bear, of the bison, of the maneless lion, and of a sort of horse with a large head recalling the wild Mongolian horse of the present day. The great Irish elk, taller than a tall horse and much larger than any of the modern deer, is represented, while there are also pictures of several creatures that cannot be identified.

A very interesting picture is one of a horse with a strap around the nose, showing that in those long-past days the horse had already been tamed by man. Another drawing is of a hornless bull, quite plainly a domesticated breed, and one that must have been domesticated for a very long time in order to reach such a hornless condition. Bisons are represented, and the auroch, or wild bull. Also there are really beautiful drawings of reindeer. The fact that reindeer could live in the South of France proves that the climate was then much colder than at present, and helps to prove that these drawings were made not very long after the last Ice Age, when all Northern Europe down to Central Germany lay under an ice-cap similar to that which now covers Greenland. It is possible, Sir Arthur thinks, that these artistic Aurignacians actually lived before the last Ice Age.

A very wonderful find has recently been made in a cave at St Martory, near Toulouse, where models of all sorts of animals worked in clay have been discovered, some complete, some unfinished, just as they were left by the prehistoric artist. One is a model of a bear cub without a head, and lying near it is the skull of a real bear. There are two large models, each about five feet long, of animals of the cat tribe, either lions or tigers. These models are believed to date back to the Magdalenian epoch, between twenty thousand and fifty thousand years ago. It would seem that this cave was the studio of the ancient sculptor, who was perhaps called away by some tribal raid from which he never returned.

We referred earlier in this chapter to the curious fact that fossilized bones of the horse are found all over the American continent. It may be interesting to add here that there has been discovered in Hava Supai Canyon, near the Colorado River, a picture, cut in the red sandstone, of an elephant attacking a man, which proves that the elephant existed with man in the New World. Why or how the elephant became extinct there it is impossible to say. On the walls of the same canyon is a rough carving of what is unmistakably a dinosaur; this is the first indication that man ever saw a living dinosaur.

Fossilized bones are generally all that man finds of extinct animals, yet the discovery of hair and hide in the case of the giant sloth is not the only one of its kind, and Sir Arthur spoke of a case which is probably unique, the discovery of the Siberian mammoth.

One day in 1908 a Siberian hunter saw foxes gnawing at something which stuck out of the earth on the edge of a river, and when he went to see what it was that they were eating he discovered the head of a mammoth exposed by a flood which had cut deep into the frozen bank of the stream. The native Siberians are superstitiously afraid of mammoth remains, and this man fled, but when he reached the nearest town, Kasachia, he spoke of his discovery, and by good luck the news came to the ears of an educated Russian, who went out at once and poured water over the head so as to form a protective coating of ice. Then he sent word of his discovery to St Petersburg, and the Academy at once dispatched a well-equipped expedition to excavate the remains.

So perfect were they found to be that the flesh was fresh and eatable. Some of it was actually thawed, cooked, and eaten, as an experiment. Truly a strange experience, to eat the meat of an animal which had died perhaps fifty thousand years earlier! The skin was taken off and sent back to Russia with the skeleton, and the whole animal was set up. And there it is to-day, looking almost as it did on the day it died.

Even the cause of the great beast's death was discovered. Its legs were twisted under it, and the scientists found that a large blood-vessel near the heart had been ruptured. It was quite clear that the animal had fallen into a hole while grazing, and that the force of the fall or its first struggle to get out had killed it. The grass which it had been eating was actually still in its mouth, showing that it had not even had time to swallow the mouthful.

Although the mammoth had a long coat of thick hair, and was therefore protected to some extent against the cold, it is fairly certain that when herds of these giants roamed the wide plains the climate of Northern Siberia was much milder than at present. Great quantities of mammoth ivory come at times to the London market. Some of the tusks are very large, and, though cracked and discoloured on the outside, they are still solid and fit to be carved into various useful objects.

Sir Arthur has travelled thousands of miles in his searches for fossil remains. Four times he went to North America, twice to South America, and he has been to Greece, Spain, and other European countries. One of his happiest hunting-grounds is in the province of Aragon, in Spain, where there is an old lake-bed containing very interesting fossils.

This part of Spain is never visited by the average tourist, and it is so wild that on the occasion of his first visit Sir Arthur wrote to the British Embassy at Madrid to discover whether it was safe to take Lady Smith Woodward with him. Getting no reply, they started out, and reached their destination without trouble. Sir Arthur got the *alcalde* (mayor) to find him men to do the digging, and they unearthed quantities of bones of the remote ancestors of our present horses and pigs. The Spaniards were convinced that these bones must be of enormous value. Otherwise, why should an English *señor* come from the other side of the world (they think that England is thousands of miles away) in order to dig for them? It was Sir Arthur's hardest task to convince them that the bones were not worth much gold, but when they did at last understand they settled down and dug nobly, and became most friendly.

When the work was done Sir Arthur expressed his appreciation by presenting the *alcalde* with a mayoral chair, and now any other English folk who visit this part of Spain are sure of a warm welcome. When at last Sir Arthur and his wife returned to England they found at their home a letter from the Embassy assuring them that it was impossible to find accommodation in Aragon and that they had better not dream of going there!

Sir Arthur Smith Woodward began his scientific career in 1882 by obtaining a post as assistant in the British Museum, and for years he worked upon fossil fishes. The Trustees gave him the task of making a catalogue of these fishes, a task which took fourteen years and ended in the production of four thick volumes. There is no branch of geology in which Sir Arthur has not exercised his talents, and he has contributed nearly three hundred papers to various scientific journals, on such varied subjects as British crocodiles, horned tortoises, the Sarga antelope, whose remains were found near Twickenham, dinosaurs from Transylvania, and great fish from the chalk of Kansas.

Sir Arthur has received the Royal Medal of the Royal Society, the Cuvier Prize of the French Academy, the Lyell Medal of the Geological Society, and in 1924 the honour of knighthood. And after nearly half a century of devotion to it he is still as keen on geological work as ever.